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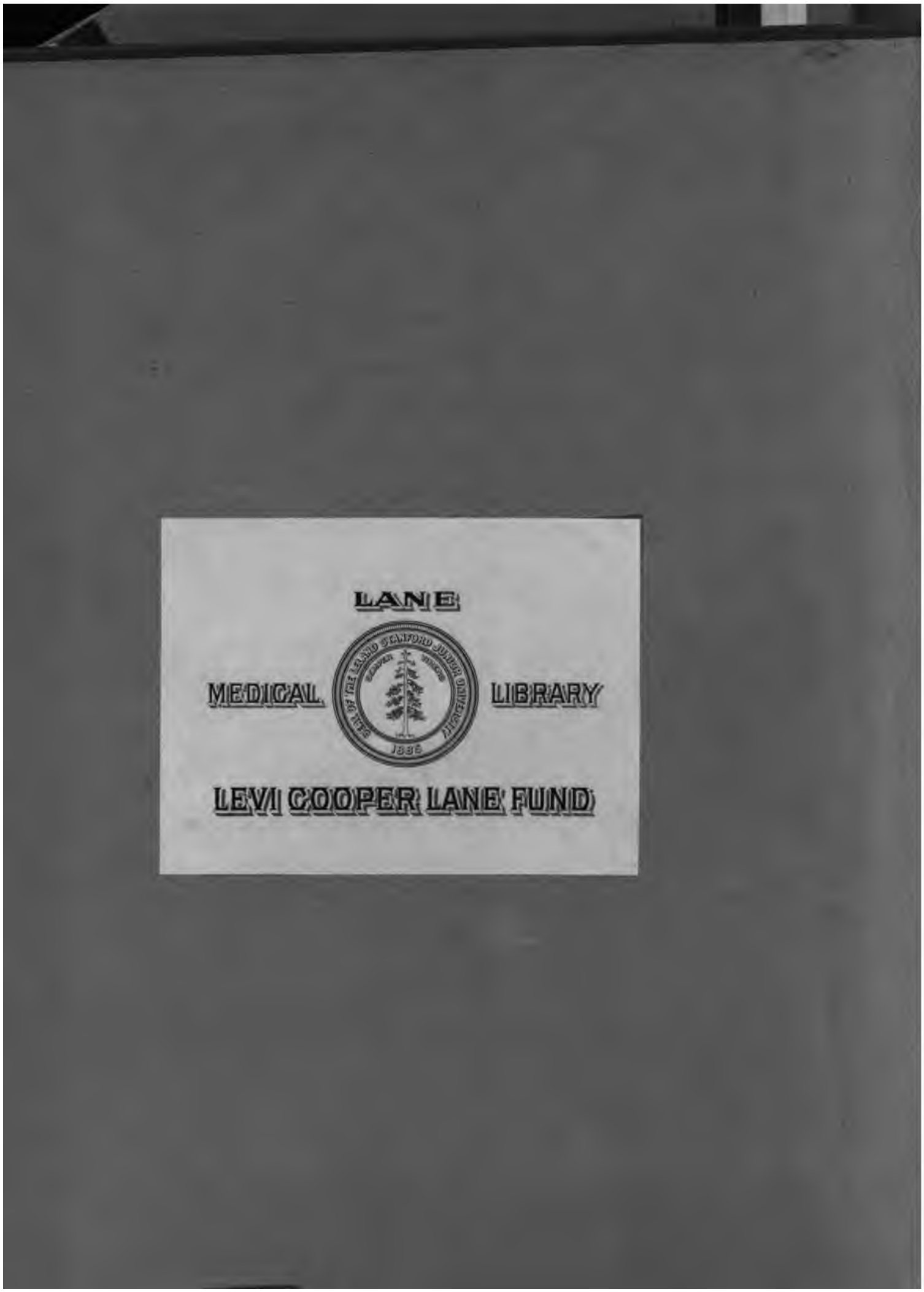

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INTERNATIONAL JOINT COMMISSION

POLLUTION OF BOUNDARY WATERS

REPORT

OF THE

CONSULTING SANITARY ENGINEER

UPON

REMEDIAL MEASURES

MARCH 8, 1916

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1918

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LETTER OF TRANSMITTAL.

THE INTERNATIONAL JOINT COMMISSION.

GENTLEMEN: I have the honor to present a report upon investigations made under my direction relative to remedial measures for the present conditions of pollution of certain boundary waters.

Respectfully,

EARLE B. PHELPS,
Consulting Sanitary Engineer.

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POLLUTION OF BOUNDARY WATERS.

SCOPE AND PURPOSE OF THE PRESENT REPORT.

These investigations were undertaken in order to secure data upon which to base a report upon the second branch of the following reference:

1. To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to the public health and unfit for domestic or other uses?

2. In what way or manner, whether by the construction and operation of suitable drainage canals or plants at convenient points or otherwise, is it possible and advisable to remedy or prevent the pollution of these waters, and by what means or arrangement can the proper construction or operation of remedial or preventive works, or a system or method of rendering these waters sanitary and suitable for domestic and other uses be best secured and maintained in order to insure the adequate protection and development of all interests involved on both sides of the boundary, and to fulfill the obligations undertaken in Article IV of the waterways treaty of January 11, 1909, between the United States and Great Britain, in which it is agreed that the waters therein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other?

Stripped of its explanatory matter the reference in question becomes:

In what way is it possible and advisable to remedy or prevent the pollution of these waters, on either side, to the injury of health or property on the other?

Satisfactory recommendations upon the *advisability* of remedial measures must be based on the one hand, upon the results of a thorough examination of existing conditions of pollution; upon the feasibility and cost of remedying these conditions wholly or in part; and upon a careful comparison of the relative value and cost of the benefits to be derived thereby. On the other hand, such an inquiry must be guided in the present reference by the terms of the treaty that the boundary waters "shall not be polluted on either side to the injury of health or property on the other."

It is understood that the advisability of this requirement itself is not in question and that it would be without the scope of the present reference to consider the merits of alternative projects, such as new sources of water supply for the lower communities, which would not accomplish this specific requirement.

It will be necessary, therefore, in this discussion of the advisability of remedies, to review the results already obtained and reported upon by the Commission relative to existing pollution of these waters and to examine these results with special reference to the nature and extent of any injury to health or property which may be attributed to pollution crossing the boundary.

Such a review involves the interpretation of bacteriological results in terms of injury and necessitates in turn a discussion of reasonable and permissible limits of pollution, the extent and character of pollution from natural drainage, the efficacy of water purification plants, and the effect upon the safe operation of such plants of increasing pollution loads. Upon these questions the Commission has had the advice of a board of consulting engineers, and the conclusions of this board will be incorporated in the present discussion. Upon the basis of these two lines of investigation—the bacteriological studies and the engineers' recommendations—it will be possible to formulate specific recommendations for a minimum requirement for the treatment of sewage entering the boundary waters. This requirement, however, will be expressed in terms of bacteria and organic improvement, and will still permit the application of alternative measures to obtain the desired results. There remains also the question of "possibility" of the required measures, which is interpreted in this case to mean the practical possibility or the feasibility of the projects, having due regard to the engineering phases and to reasonable limits of cost.

In order to determine in each individual case what specific treatment of the sewage will accomplish the desired result and the feasibility and advisability of the suggested treatment, it has been necessary to make extensive field and office studies of drainage and treatment plans in the more important cases. For the purpose of the present reference and report it was deemed advisable and sufficient to confine these detailed studies to the St. Clair, Detroit, and Niagara Rivers. Upon the latter two streams are situated the two largest cities existing along the boundary rivers, and these waters are accordingly by far the most seriously polluted. In these two cities the most important and difficult engineering problems are to be found and will have to be solved. Feasible remedies developed in these two cases will therefore be feasible in

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the smaller communities, while the advisability of remedies in the case of the latter will necessarily depend upon the advisability of a general policy of improvement determined primarily by the conditions in the major cities upon which the burden of expense must fall.

The St. Clair River was included in the studies as a case of less serious pollution. It seemed desirable to include this stream within the Detroit district in order that the question of advisability of remedies might be discussed from all viewpoints. Representing as it does the most polluted of those streams which will not, under the broad terms of the reference, require immediate treatment, this river serves as a useful illustration of a case where the strictly local aspects of the situation demand more stringent treatment than would be justified by the results to be attained from an international viewpoint.

These studies have been of the nature of preliminary engineering investigations of certain alternative projects of main drainage lines and treatment works. They have in each case been carried sufficiently far as to detail of basic data and of design to justify preliminary engineering estimates of cost and a general statement of feasibility. While these studies have been thorough, they are for the most part based upon existing field data and upon office study and compilation of available material. There has been no attempt to make them comprehensive, nor has it been deemed necessary or advisable to develop the projects recommended in sufficient detail to justify their adoption without further engineering studies. A single feasible solution, selected in each case from a few alternative projects, has been adopted as being sufficient to demonstrate the feasibility of the general policy. Further studies based upon the data of special field work may readily develop more economical drainage lines, while progress in sewage treatment will almost certainly indicate further economies in that direction. In particular, no study has been made of the possibilities of treating sewage by aeration, a new and undeveloped method now in the experimental stage, but holding promise of future possibilities.

In brief, the engineering studies have developed feasible plans of collection and disposal at all important points on the three most seriously polluted connecting rivers and have determined the upper limits of cost of these improvements with a degree of precision that will be best appreciated by reference to the detailed reports upon the work by the district engineers in charge.

Finally, the present discussion and report brings together the data from these various lines of inquiry and formulates a reply to the second branch of the reference. This reply is in the form of a proposed policy expressed in terms sufficiently broad and general to be applicable to the international boundary waters as a whole at the present time and in the future, and at the same time so detailed and concrete as to indicate definitely the present requirements in specific cases.

The reference also calls for an inquiry as to the best arrangement for the operation and maintenance of the remedial works. The administrative control of pollution in the boundary waters is obviously a Federal rather than a State or Provincial matter. The magnitude of the work, the diverse jurisdictions involved, and the necessity for international cooperation and uniform development upon the two sides of the boundary emphasize this fact. The proper administrative supervision of any international policy for the protection of these waters demands periodical examinations of the waters and of the remedial works. The administrative body must have authority to enforce the established policy as to present requirements, increasing requirements with growth of population, and the inclusion of other streams within the scope of the policy at such times as the increased population upon those streams may determine.

Such an administrative body must be international in character, and it should be a continuing body with a reasonably fixed policy and procedure. As the matters involved are primarily health matters and in no way affect navigation or property interest other than through the health of the people, the Federal health authorities of the two Governments would quite naturally and logically constitute, or nominate, the joint administrative body for the direct enforcement of the continuing policy of stream protection.

EXTENT AND SEASONAL DISTRIBUTION OF POLLUTION AS DISCLOSED IN THE PROGRESS REPORT.[1]

GENERAL.

The bacteriological investigations were begun in April and continued through October, 1913. Individual stations were under observation for consecutive periods of from 14 days to 3 months. Bacteriological examinations alone were made and results are reported showing the numbers of bacteria growing at 20° C. and at 37° C. and the numbers of B. coli, a characteristic intestinal organism. Upon the basis of these results certain conclusions relative to the pollution of the waters were made. In certain portions of the Great Lakes and in all the connecting waterways serious pollution was shown to exist, although the great body of lake water itself is for the most part remarkably pure. Both maximum and average results for the periods of observation at each station are reported, and attention is directed to the diver-

[1] Progress Report of the International Joint Commission, in re The Pollution of Boundary Waters, including the report of the sanitary experts. Jan. 16, 1914.

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gence of daily results from the average as indicating intermittency of pollution. Maximum results are frequently 10 times as great as short-period averages, a point of significance in any discussion of water supply.

SEASONAL VARIATION.

Careful analysis of the results discloses another kind of variation, the consideration of which leads to important deductions. This is the seasonal variation.

Studies that have been made in the past of the pollution and self-purification of streams have indicated a direct dependence of self-purification upon the temperature of the water. At points somewhat remote in terms of time from the point of pollution the streams show less residual pollution at the higher temperatures and a maximum condition of pollution during the winter months.

In the case of the boundary rivers, the time of passage is relatively short, so that no evidence of material improvement from self-purification need be expected. A quite unexpected and hitherto unnoted phenomenon has, however, been shown in this case, namely, a great increase in the bacterial evidence of pollution in the warmer months. This effect is shown so consistently in the work of the several laboratories, and upon the various rivers, that there can be no doubt of its reality. It is hardly to be believed that there is actual multiplication of the intestinal organism in the streams themselves, although this possibility can not, with our present knowledge, be entirely eliminated. It is more probable that the bacterial content of the sewage shows a seasonal variation. Whether this be traceable to actual multiplication of intestinal bacteria within the sewers or to a greater per capita discharge of these organisms in the warmer months can not be stated. In either case the observed result is of immediate and direct significance. The presence of the organism B. coli is in the case in hand directly and quantitatively indicative of human pollution. The known characteristics of the organism justify the belief that its reaction to environmental conditions is not unlike that of true pathogenic or disease producing bacteria, especially the typhoid germ. In the absence of contrary evidence, therefore, the B. coli from sewage is universally accepted as a quantitative measure of dangerous pollution, and whether the observed summer increase in numbers of this test organism be attributed to increased proliferation within or without the body, the accepted significance is in no sense altered.

The quantitative extent of this seasonal variation is of immediate interest in any study of the effect of pollution upon water supplies. The data of the Progress Report available for this purpose have accordingly been brought together for analysis. These data include the results of all examinations made at the same sampling station or cross section over two or more distinct seasonal periods. Such stations were found upon the St. Clair, Detroit, Niagara, and St. Lawrence Rivers. Certain comparisons have also been included between two river sections which, although not identical, are separated by short stretches in which there is no appreciable additional pollution. The results of this study are remarkably consistent for the various rivers and seasons, and taken together give the average seasonal effect for 1913, shown in Table I.

TABLE I.—*Seasonal distribution of B. coli in the St. Clair, Detroit, Niagara, and St. Lawrence Rivers, 1913.*

[Numbers are percentages of mean value for season of May–September.]

Month.	Relative number of B. coli.
May	26
June	61
July	129
August	231
September	53

Investigations upon the Detroit River by Hubbell in 1915 gave results strikingly similar in general form, but showing a less decided drop in the fall months.

For comparison with these results there is given in Table II a summary of the results of water examination at Buffalo during the years 1906–1914, inclusive. Daily examinations of 1 cubic centimeter samples were made. The table gives the total number of positive tests recorded during this period. There is also included a summary of total deaths from typhoid fever in Buffalo during the same period. The information contained in this table is taken from the annual reports of the Buffalo board of health.

TABLE II.—*Seasonal distribution of typhoid fever (total deaths) and B. coli (total positive tests recorded in 1 cubic centimeter) in Buffalo, 1906–1914.*

Month.	Typhoid, total deaths.	B. coli, total positive tests.
January	45	53
February	51	39
March	39	33
April	44	31
May	46	44
June	26	52
July	54	102
August	68	63
September	92	37
October	93	60
November	73	52
December	68	70

The results of Tables I and II are plotted together for the season May–October in Plate I. The figures

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for typhoid deaths are set back one month to bring out any relationship existing between them and the bacterial pollution. Even making due allowance for the expected fall increase in typhoid fever from other causes than water supply there is agreement between these curves which is more than mere coincidence. Further discussion of the importance of the seasonal variation here disclosed will be deferred until the matter of interpretation and standards is considered. The ratios of Table I, however, are so definitely established that they will be employed in the further discussions of the extent of pollution of the boundary waters.

EXTENT OF POLLUTION.

Taking up now the actual extent of pollution shown in the Progress Report, this may be briefly summarized as follows, the pollution being expressed in each case in terms of B. coli per 100 cubic centimeters.

ABOVE LAKE HURON.

The waters of Rainy Lake showed a minor but quite unexpected pollution. The river itself shows the effect of pollution from Port Frances and International Falls, which, in July, 1913, resulted in an average B. coli value across the river below these cities of 270. This pollution remains practically constant throughout the length of the river and distinctly affects the waters of the Lake of the Woods in the vicinity of the river mouth.

Lake Superior showed extensive pollution in the Thunder Bay region, especially in front of Port Arthur and Port William.

The St. Marys River contained 17 B. coli per 100 cubic centimeters at its source, increasing to 281 below the "Soo" and continuing at this figure into Lake Huron. The Straits of Mackinac were found to be quite pure.

ST. CLAIR RIVER AND LAKE.

The lower end of Lake Huron showed unmistakable evidence of steamboat pollution.

The St. Clair River was found to be reasonably pure at its upper end, steamboat pollution accounting principally for the 9 B. coli found. Above Sarnia the figures reached 41 during August, 1913; and below Sarnia and Port Huron they ranged from 22 to 763 at various cross sections. Examinations at single stations during the first 15 days of August gave results of from 106 to 1,228. The average of all examinations of this stream made during the season, 1,198 samples, is 254 B. coli per 100 cc.

The mouth of the Black River gave an average value of 3,400, showing its gross pollution.

Lake St. Clair showed very little effect from the pollution of the St. Clair River. It was found to be moderately polluted by shipping, especially at its lower end.

DETROIT RIVER.

The Detroit River was more fully studied than any of the waters hitherto described. The discussion of seasonal variation is based largely upon the data of this river. Whereas the average condition of the streams that have been dealt with is given with sufficient accuracy by averaging the results of cross sectional studies, such a procedure is not satisfactory in such a highly polluted stream as the Detroit. The influence of the highly concentrated shore pollution can not be properly weighted in any selection of sampling stations however carefully made.

On the other hand, the average value of a large number of samples will tend to eliminate sampling errors in any one section of the river, and a check upon the general accuracy of the average is obtained by a comparison of results at various cross sections between which little or no additional pollution is contributed. The data on the Detroit River are sufficiently extensive for this purpose but extend over varying seasonal ranges and because of the marked seasonal changes already described do not permit direct averaging.

Table III contains a summary of all data on cross sections below the River Rouge in the region where additional pollution is small in contrast with that added above. In order to determine the general average character of the water in this region the data have been submitted to the following treatment.

TABLE III.—*Extent of pollution of the Detroit River.*

[Data from Progress Report.]

Section.	Period.	Number of samples.	B. coli.	Seasonal factor.[1]	B. coli mean seasonal value.	Weighted average B. coli for section.
Below River Rouge.	May 27–July 16..	150	4,533	2.00	9,066	
	Sept. 4–Oct. 2...	135	785	5.56	4,360	
	Oct. 11–14.....	72	158	133.00	21,000	
						9,670
Upper end Grosse Isle.....	June 18–July 31..	250	10,900	.77	7,700	
	Oct. 4.....	10	50	58.80	2,940	
						7,510
Opposite Grosse Isle, outside.....	June 23–July 31..	137	2,607	.77	2,030	
	July 3–31.....	132	3,328	.64	2,130	
	Sept. 9–25.....	75	344	5.26	1,810	
	Oct. 7–13.....	46	17	118.60	2,000	
Weighted average....					2,095	
Opposite Grosse Isle, inside.....	Sept. 11–25.....	89	11,688	5.56	65,000	
	Oct. 7–13.....	83	153	118.60	17,950	
Weighted average....					43,500	
						8,500
Below Grosse Isle...	July 21–31.....	100	11,592	.50	5,800	
	Sept. 6–25.....	207	1,760	3.57	6,280	
	Oct. 6–10.....	101	74	100.00	7,400	
						6,440
Grand average weighted		1,487				8,030

[1] Ratio of mean seasonal value and that of mid period date, from seasonal distribution curve, Pl. I.

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Individual series of results on one cross section are first averaged to give an approximate cross sectional value at the mid date of the series. This value is reduced to a mean seasonal value by use of a seasonal factor derived from the seasonal distribution curve, Plate I. The two or more series of determinations made at each section and reduced to mean seasonal values are then averaged, each weighted by the number of samples involved. The result is put down as the average cross sectional value at this point during the season May–September. Four sections are thus treated, the first immediately below the River Rouge, the second at the upper end of Grosse Isle, the third opposite Grosse Isle, on both sides, and the fourth below Grosse Isle.

The average values obtained at these four sections by this procedure are in substantial agreement and indicate the extent of pollution of the Detroit by the population upon its shores. This agreement also indicates that the methods employed in this analysis and the seasonal distribution results derived from the data of four rivers are sufficiently accurate for the present purpose. The weighted average of the four sections is 8,030 B. coli per 100 cubic centimeters, a figure which will be taken as representative of the average extent of pollution May 1 to September 30, 1913.

From this mean value and the curve of seasonal variation there can now be derived a corrected statement of conditions during the remainder of the season covered by the data. This result is shown in Table IV.

TABLE IV.—*Extent and seasonal distribution of pollution, Detroit River.*

[Computed from mean seasonal value and seasonal distribution curve.]

Month.	Seasonal factor.	B. coli per 100 cubic centimeters.
May	0.26	2,090
June	.61	4,900
July	1.29	10,350
August	2.31	18,550
September	.53	4,260
Mean	1.00	8,030

This table gives a reasonably accurate picture of the actual extent of the pollution of the Detroit River as affected by seasonal variations. Other causes of variation and their effects will be discussed in a later section.

LAKE ERIE AND NIAGARA RIVER.

The western end of Lake Erie was found to be so noticeably affected by the pollution entering by the Detroit River as to be unsafe for use on steamers. Outside of a line from Point Pelee to Sandusky, however, the water was found to be quite pure. The eastern end of the lake showed some pollution from navigation and some shore pollution confined quite closely to the immediate shore waters.

The waters of the Niagara River were studied extensively, although not in such detail or over as large seasonal range as in the case of the Detroit. The peculiar nature of the channels between Buffalo and the Falls makes it difficult to obtain, from the data, cross-sectional values as a measure of the total pollution. Four series of examinations are, however, available for the purpose, two near the mouth of the river, one a single set of 40 samples just below the Falls, and one near the lower end of Goat Island. These results have been treated as in the case of the Detroit River, in Table V.

TABLE V.—*Extent of pollution of the Niagara River.*

[Data from Progress Report.]

Section.	Period.	Number of samples.	B. coli.	Seasonal factor.	B. coli mean seasonal value.
Below Goat Island	May 30-June 16	183	2,200	2.04	4,490
Below Falls	June 14	40	2,020	1.69	3,410
Mouth	May 29-June 12	90	2,016	2.22	4,470
Do	Aug. 1-14	95	10,100	.39	3,940
Average	May 1-Sept 30	408	(Weighted.)		4,250

The mean seasonal value, 4,250, gives, as previously, the following monthly values for the Niagara River:

TABLE VI.—*Extent and seasonal distribution of pollution, Niagara River.*

[Computed from mean seasonal value and seasonal distribution curve.]

Month.	Seasonal factor.	B. coli per 100 cubic centimeters.
May	0.26	1,100
June	.61	2,590
July	1.29	5,480
August	2.31	9,820
September	.53	2,250
Mean	1.00	4,250

It is now possible also to compare the mean values obtained upon the Detroit and Niagara Rivers with the respective contributing populations, the stream volume being practically the same in the two cases. This comparison is given in Table VII.

LAKE ONTARIO AND THE ST. LAWRENCE.

The pollution of the Niagara River was found to extend into Lake Ontario for 10 or 12 miles and at times 16 miles from the river's mouth. The direction and extent of this influence was found to be condi-

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tioned by the direction and velocity of the wind. It was noticed that the polluted water moved as a whole, suffering but little change by dilution or diffusion.

TABLE VII.—*Extent of pollution, Detroit and Niagara Rivers, in terms of contributing population.*

River.	Population.	B. coli per 100 cubic centimeters. Average, May–September.	
		Total.	Per 1,000 population.
Detroit	780,000	8,030	10.3
Niagara	500,000	4,250	8.5
Mean (weighted)			9.5

The lower end of Lake Ontario was found to be almost sterile before the season of navigation. It was slightly polluted later in the season by boats. The Kingston water front was found seriously polluted. Minor and intermittent pollution was observed about the Thousand Islands, rendering the waters unsafe for local domestic consumption at these points.

In the region about and below Ogdensburg an average B. coli value of 20 was obtained May 9–16, and of 138 August 1–27. Reduced by the seasonal factors, these become 59 and 41, respectively, average 50 for the May–September season. The number of examinations is too few for definite comparison with the other rivers, but taking the mean discharge value of 240,000 second-feet for the St. Lawrence as compared with 210,000 second-feet for the Niagara (Lake Survey Bulletin No. 24, 1915, U. S. War Department), the pollution at this point is representative of a population of about 6,000 on the basis of the Niagara and Detroit values. It is not known what proportion of the 21,000 total population at this point is actually connected with the sewerage system.

THE ST. JOHNS.

The St. Johns River showed pollution amounting to about 125 B. coli per 100 cubic centimeters in the late fall, October 7–November 4, which in the light of the seasonal curves obtained elsewhere, indicate a mean May–September pollution value of at least 9,400. This is excessive in comparison with the Detroit and Niagara River figures, population and stream flow considered. Assuming a low run-off of 4,000 second-feet for the St. Johns in October, the B. coli figures per capita are about 65 times as great in this case as in the others. This abnormal condition was attributed in large measure to the potato-starch factories located along this river, the waste from which contains large numbers of bacteria. In this case, therefore, the B. coli do not represent pollution of a dangerous sort.

VARIATION FROM AVERAGE CONDITIONS.

While the average results derived in this way are convenient and necessary in discussing the extent of pollution and remedies therefor, it is particularly important to note the departures from the average, both seasonal and as to cross sections. The long time seasonal variations have been sufficiently set forth in Tables IV and VI. In addition to these there are short-time variations extending over periods of from one to seven days, due to actual fluctuations in stream discharge. Maximum fluctuations in this factor may be taken at approximately 25 per cent either way of the mean, and will result in departures of a similar magnitude from the mean index of pollution. Geographically, or as regards the cross section, there is even wider departure from the average conditions, the maximum values ranging from 2 to 15 times the mean cross sectional value. These variations are of immediate interest in connection with water supplies and indicate the importance of a proper study of the location of waterworks intakes.

SIGNIFICANCE OF THE POLLUTION DATA.

The significance of the bacterial evidence of pollution must be considered from the point of view of its magnitude, its seasonal and geographical distribution, and its actual relation to the bacteria of disease. The practical limitations of water purification must also be considered. The first two of the matters have already been discussed.

RELATION TO WATER SUPPLIES.

Experience has shown that there is a distinct relation between B. coli values in a polluted water and the incidence of typhoid fever in communities using such water. This relation is not well fixed numerically, but with improved methods of study and with the general reduction in typhoid fever rates, it is becoming increasingly apparent that high drinking water standards are essential. Where formerly a standard of 50 B. coli per 100 cubic centimeters was considered permissible in a drinking water, the tendency of the times, based upon experience, is toward more severe standards, such as 10 or less per 100 cubic centimeters. With improved methods and decreased cost of water purification it is not improbable that even better results will be demanded in the future, and will be found to be justified.

It is obvious, therefore, that the waters of the connecting rivers, which are most important in connection with municipal water supplies, are not fit for domestic consumption without purification, and could not by any feasible method be protected to that extent.

OPINION OF CONSULTING ENGINEERS.

This matter was discussed before the Commission by a board of consulting engineers, and the following

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résumé of their testimony represents the opinion of that board:[1]

1. Speaking generally, water supplies taken from streams and lakes which receive the drainage of agricultural and grazing lands, rural communities, and unsewered towns are unsafe for use without purification, but are safe for use if purified.

2. Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are safe for use after purification, provided that the load upon the purifying mechanism is not too great and that a sufficient factor of safety is maintained, and further provided that the plant is properly operated.

3. As, in general, the boundary waters in their natural state are relatively clear and contain but little organic matter the best index of pollution now available for the purpose of ascertaining whether a water purification plant is overloaded is the number of B. coli per 100 cubic centimeters of water expressed as an annual average and determined from a considerable number of confirmatory tests regularly made throughout the year.

4. While present information does not permit a definite limit of safe loading for a water-purification plant to be established, it is our judgment that this limit is exceeded if the annual average number of B. coli in the water delivered to the plant is higher than about 500 per 100 cubic centimeters, or if in 0.1 cubic centimeter samples of the water B. coli is found 50 per cent of the time. With such a limit the number of B. coli would be less than the figure given during a part of the year and would be exceeded during some periods.

5. In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby.

6. While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters.

7. The nature of the sewage treatment required should vary according to the local conditions, each community being permitted to take advantage of its situation with respect to local conditions and its remoteness from other communities, with the intent that the cost of sewage treatment may be kept reasonably low.

8. In general, the simplest allowable method of sewage treatment, such as would be suitable for small communities remote from other communities, should be the removal of the larger suspended solids by screening through a one-fourth-inch mesh or by sedimentation.

9. In general, no more elaborate method of sewage treatment should be required than the removal of the suspended solids by fine screening or by sedimentation, or both, followed by chemical disinfection or sterilization of the clarified sewage. Except in the case of some of the smaller streams on the boundary, it is our judgment that such oxidizing processes as intermittent sand filtration and treatment by sprinkling filters, contact beds, and the like are unnecessary, inasmuch as ample dilution in the lakes and large streams will provide sufficient oxygen for the ultimate destruction of the organic matter.

10. Disinfection or sterilization of the sewage of a community should be required wherever there is danger of the boundary waters being so polluted that the load on any water-purification plant becomes greater than the limit above mentioned.

11. It is our opinion that, in general, protection of public water supplies is more economically secured by water purification at the intake than by sewage purification at the sewer outlet, but that under some conditions both water purification and sewage treatment may be necessary.

12. The bacteriological tests which have been made in large numbers under the direction of the International Joint Commission indicate that in most places the pollution of the boundary waters is such as to be a general menace to the public health should the water be used without purification as sources of public water supply or should they be used for drinking purposes by persons traveling in boats.

13. It is our judgment that the drinking water used on vessels traversing boundary waters should not be taken indiscriminately from the waters traversed, unless subjected to adequate purification, but should be obtained preferably from safe sources of supply at the terminals.

14. While recognizing that the direct discharge of fecal matter from boats into the boundary waters may often be without danger, yet in the interest of effective sanitary administration it is our judgment that the indiscriminate discharge of unsterilized fecal matter from vessels into the boundary waters should not be permitted.

[1] International Joint Commission. Résumé of testimony of consulting sanitary engineers, Washington, 1914.

APPLICATION.

Accepting these conclusions in their general sense, there would be required a bacterial removal on the part of the water filters of 90 per cent to reduce the B. coli from 500 per 100 cubic centimeters, the extreme permissible value established, to 50 per 100 cubic centimeters, the most lenient drinking water standard of the past, or of 98 per cent to accomplish the standard of 10 per 100 cubic centimeters representative of the better present-day practice. An efficiency of 98 per cent represents about the average performance of a well regulated plant without the use of disinfectants. Conservative procedure would tend to balance the possibilities of more perfect purification, by disinfection or by new and improved methods, against the probable future demands of sanitary sience for better standards in water supplies.

If further evidence as to the reasonableness of the conclusions of the consulting engineers be required, reference might be made to experiences at existing works where waters are being treated which are more polluted than this standard would permit. Two such cases come readily to mind, Lawrence, Mass., and Philadelphia, Pa. In both instances epidemics of typhoid fever have resulted from accidental breakdowns due in the one instance to freezing of the filter bed during cleaning and in the other to a break in a raw water supply pipe. While such accidents are exceptional, they are in no sense rare, and can never be fully guarded against. In addition to these accidental happenings of exceptional occurrence it is readily con-

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ceivable that there are more frequent, if less serious, interruptions in the filter service ranging in magnitude all the way from the daily fluctuations in efficiency, so well known to filter managers, to the less frequent but more serious failures due to varieties of causes. While the net effect of such fluctuations during a single year is not great and may readily be concealed in a statement of average performance, their frequency and magnitude are of the greatest significance in determining the general wholesomeness of the water supply and its effect upon the health of the consumer, matters which can not be expressed in averages. In the case of Lawrence, it is not possible to arrive at a definite statement of the actual character of the Merrimack River from existing data. B. coli is reported in 100 per cent of the cases in 1 cubic centimeter samples. A careful study of experimental filter operation and relative numbers of B. coli and of other bacterial groups, which latter have been determined and reported quantitatively, indicates that the character of the Merrimack River is neither very much better nor very much worse than the estimated limit of pollution of 500 B. coli per 100 cubic centimeters. This pollution represents the sewage of approximately 100,000 people 10 miles above, with the resulting self-purification which comes from a mean low-water storage period of 1.2 days in a 10-mile stretch of back water behind the dam at Lawrence. On the basis of mean annual run-off and Detroit and Niagara values previously derived, this pollution factor indicates a purification of between 95 and 98 per cent in the Merrimack River between Lowell and Lawrence. No corrections are possible, however, for seasonal effect or for the very great fluctuations in stream flow. In 1913, the last year for which complete data are available, the filter effluent showed B. coli in 1 cubic centimeter 15.7 per cent of the time, indicating approximately 16 B. coli per 100 cubic centimeters in the water supplied to the city. While the typhoid fever statistics in this case do not permit of definite conclusions regarding the relation of this water supply to the typhoid fever of the city, it is noticeable that the typhoid death rate in Lawrence is exceeded by that of only one city in the State of 50,000 or more inhabitants. In the single exception a higher rate is justly attributable to an excessive number of hospital cases. Further evidence of this general character might be extended and will undoubtedly be accumulated as the importance of higher standards in domestic water supplies becomes better appreciated. For the purposes of the present report, however, it will be assumed, without further discussion, that the pollution of boundary waters can not be permitted to exceed that which will give 500 B. coli per 100 cubic centimeters as a mean cross sectional value.

The upper limit of 500 B. coli per 100 cubic centimeters was also suggested as a yearly average. In view of the extraordinary seasonal variation disclosed by the present study of the data of the Progress Report, the extent of which was not known to the consulting engineers at the time; and in view of the absence of data covering the winter months, it has been decided to deal in the present report with the mean seasonal value for the period, May to September, inclusive, 1913, deduced from the analytical data by means of a seasonal curve.

On the basis of the 1913 data, this mean value is exceeded throughout the months of July and August, and the maximum value is, for a short period, about 2.6 times the mean.

NECESSARY EFFECTIVE DILUTION.

The mean seasonal value for the Detroit and Niagara Rivers, taken together and properly weighted by populations, is 9.5 B. coli per 100 cubic centimeters per 1,000 population. This mean is taken as the best representative value for the present purposes, although the possibility exists, and is suggested by some evidence in the Progress Report and elsewhere, that the per capita pollution increases with increasing concentration of population. The difference in the values below Detroit and Buffalo, respectively, has already been pointed out in Table VII. The value given for the St. Clair River reduces to a mean seasonal value approximately six-tenths of the Detroit result, while in the case of the small communities on the St. Lawrence the pollution index was shown to account for less than one-third the population on the basis of the Detroit values. The use of the mean Detroit-Buffalo value will serve the present purpose with sufficient accuracy until a more careful adjustment of values is made possible by more complete and extensive bacteriological data. Taking as the mean run-off the round figure 210,000 second-feet for each of these rivers, it is found that with a river run-off of 1 second-foot per capita of contributing population, the B. coli will be approximately 2,000 per 100 cubic centimeters, so that there is required a dilution of 4 second-feet per capita in order that dilution alone shall reduce the index of pollution to the established limit of 500. This value of 4 second-feet per capita may be taken as the necessary effective dilution, and may be regarded as the quotient of the actual dilution by the fraction of polluting material left after sewage treatment. For example, if the actual dilution be 1 second-foot per capita, it will be necessary by proper treatment to reduce the contributing sewage to one-fourth of its initial value in order to bring up the effective dilution to four.

EXTENT OF SEWAGE TREATMENT PROPOSED.

Upon this basis the present and future requirements of any particular case are readily computed. The flow of the Detroit and Niagara Rivers, approxi-

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mately 210,000 second-feet, will receive the discharge of 52,500 persons without treatment, or of twice that number with a 50 per cent removal of polluting material, or of 10 times that number with a 90 per cent removal. Taking the present population on the Detroit River at 780,000, this leads to an indicated removal by sewage treatment of 93.5 per cent, while with a future population of 1,000,000 the corresponding purification factor for the same effective dilution will be 95 per cent. Similarly, a purification factor of 90 per cent will be necessary upon the Niagara River for the present population of approximately 500,000.

While these statements are based primarily upon examinations and standards, both in terms of B. coli, it must not be overlooked that this organism is accepted merely as a convenient indicator of sewage, and that other harmful polluting agencies must be dealt with upon the same basis. Sewage treatment deals with three types of harmful pollution—organic matter which may putrefy, solid matter which may deposit or interfere with filter operation, and bacteria. In the present case putrescible organic matter gives no concern, because the dilution limits imposed by the other two factors are far beyond those necessary in dealing with this particular feature. Suspended solids, or "solids capable of settling," as used in sewage analysis, are undesirable because of their effect upon the treatment of water supplies. The extent of purification indicated in the case of bacteria will also be adopted, therefore, for suspended solid matter.

DISTRIBUTION OF RESPONSIBILITY.

In considering the burden of responsibility, it has been assumed that it is individual and to be borne equally by all concerned. The larger cities, by reason of their greater populations, are called upon to bear the greater costs of remedying conditions, so that the burden of this cost falls more heavily upon the American cities than upon the Canadian. Considering the boundary waters and communities as a whole, however, there is found to be a condition calling for remedial measures in which the individual contributions are supposedly equal and call for equal treatment. It is therefore concluded that the specified degree of treatment will be applied in all cases, leading to an approximately equal division of the costs per capita. Increased populations upon either side of the boundary will lead to increased standards of quality in the treated sewage. Only by such a procedure can the maximum development of the natural resources of the streams be attained with a minimum of imposed burdens.

ENGINEERING INVESTIGATIONS.

The degree of purification indicated in these studies as necessary for the protection of these boundary waters has been made the basis of detailed engineering investigation as to the feasibility and cost of accomplishing the desired results.

ORGANIZATION AND SCOPE.

For this purpose engineering offices were established at Detroit, Mich., and at Buffalo, N. Y., under the immediate supervision of District Engineers Henry C. McRae and Frank C. Tolles, respectively. The district covered by the Detroit office included all cities and towns upon both sides of the St. Clair and Detroit Rivers, and that under the Buffalo office all cities and towns upon both sides of the Niagara River. The organization in each of these offices was essentially the same, and comprised a district engineer, one assistant engineer, and two draftsmen, together with a clerk. In the case of the two principal cities involved, complete studies were made of the main drainage systems for the collection of sewage at a site or sites suitable for disposal. The studies were based primarily upon "present populations," these being taken as the estimated population at such a date in the near future as would be selected in each case for the design of works to be built about 1920. In order that the plans might be comprehensive, however, estimates of future growth, both as to magnitude, character, and direction were made, and the requirements of the future are provided for as fully as possible. Since these two cities contribute the major part of the existing pollution, and since the solution of their specific problems represents the greater part of the financial outlay necessary in the protection of the boundary waters, most of the work of the district offices was spent upon them. The problems of the smaller communities, however, received as detailed and careful study as the necessities of the situation seemed to indicate, and in each case drainage and treatment plans have been prepared in sufficient detail to permit the estimate of initial costs and of annual capital charges, including costs of operation. In each instance satisfactory drainage lines have been found, and suitable sites for the necessary treatment works have been located. A detailed description of this phase of the work, with the estimates of costs involved, will be found in the reports of the district engineers submitted herewith. The present discussion will deal with these matters only in sufficient summary to indicate the nature of the conclusions arrived at.

METHODS OF TREATMENT APPLICABLE.

The nature of the problem as thus far outlined does not necessitate any very extensive discussion of sewage-treatment methods.

OXIDATION PROCESSES.

Since the removal of organic matter, from the standpoint of its putrifactive tendency, is not indi-

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cated in this case, those major processes of sewage treatment which involve the oxidation of organic matter need not be considered. The maximum useful development of the natural resources existing in these waters, alluded to in the reports of the consulting engineers, demands that the purely oxidizing capacity of these streams be taken advantage of, and it is readily apparent that this is sufficient for all present and future needs. Conditions of local physical nuisance now so noticeable about the water fronts of both Detroit and Buffalo, in common with many of the lake-front cities, indicate that the maximum advantage of diffusion has not been utilized in these cases, and that careful attention must be given to this matter in the design of outfall works.

REMOVAL OF SUSPENDED MATTER.

For the removal of the suspended matter capable of settling, which material is undesirable in the stream, not because of its organic character, but by reason of its physical condition, there are two major systems available, namely, fine screening and sedimentation. Careful consideration has been given to the respective merits of these two systems, and for the purposes of this preliminary investigation of possible remedies it has been found desirable to base estimates upon sedimentation in preference to fine screening. This course is conditioned upon several factors, one of these being lack of complete information on the possibilities of the newer developments in the direction of screening. Assuming, however, that screens may be developed to a point of efficiency approximating that which is possible with sedimentation, a claim which is not yet justified by experimental data, the comparative estimated costs of the two systems fails to justify the recommendation at the present time of a purely mechanical system, subject to all the inherent weaknesses of machinery, in preference to the better understood tank devices. In the case of the smaller communities, by reason of the disproportionate operating expenses incidental to the mechanical plant, the total annual cost item, taken as the sum of interest charges, operation, and depreciation, is distinctly in favor of sedimentation. In the two major cities costs are more nearly equal, but there is still a slight difference in favor of sedimentation. These respective costs are largely influenced by the further necessity for some form of chemical disinfection. This treatment requires storage tanks of a capacity at least one-half that required for sedimentation, unless existing conditions as to sewer outfall permit the substitution of such an outfall for the contact tanks. This fact, coupled with the conclusion that screened and unsettled sewage will require a somewhat larger dosage of disinfectant for results of equal efficiency, brings the total charge of the two processes much more nearly together than would be the case were the disinfection not an integral part of the treatment. Further studies based upon more detailed data as to operating costs and results under conditions of American practice may lead to a reversal of the conclusions arrived at in this comparison, which are in no sense final. As the purpose of this investigation has been to establish the major fact of the feasibility of treatment to a specified degree, and of approximate upper limits of costs involved in such treatment, and as feasible and reasonable treatment can be indicated along the more conservative lines of sedimentation and coincident disinfection, the tentative selection of this type of treatment and estimates of its costs suffices to furnish the required information.

Of the various possibilities in sedimentation devices, the Imhoff tank represents the latest development and presents marked advantages over other and earlier types of treatment. Its particular advantage lies in the comparative freshness and freedom from secondary decomposition of the sewage effluent, absence of undesirable odors about the works, and particularly the innocuous character of the sludge produced. This material may be readily dried upon sludge beds and disposed of in any convenient way without local nuisance.

REMOVAL OF BACTERIA.

In connection with bacterial removal, there is also no necessity for a discussion of alternative methods. Treatment with chloride of lime or bleaching powder has now been developed to a practical working method, and sufficient data are readily available upon which to base cost estimates. Alternative processes, such as treatment upon oxidizing filters or the use of liquid chlorine or other chemical disinfectants, are all so much more expensive that their further consideration need not be entered upon.

DRAINAGE CANALS.

GENERAL CONSIDERATION.

The reference specifically refers to the use of drainage canals as a possible remedial measure. The construction of such canals must obviously be conditioned by other uses than that of mere sewage disposal. This matter has therefore been given careful and detailed consideration, with reference not to the desirability of constructing a canal for purposes of sewage disposal but to the possible advantages of utilizing a canal to be constructed for other purposes, power development and shipping, as an alternative to the river for the disposal of sewage. In no case save that of the American cities on the Niagara frontier has there been any special study of a canal project, and no attention will be given to this particular phase

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of the reference save in this single case. The primary function of this canal project is the development of water power, but incidental to such development there are certain possibilities of improved shipping facilities and of the utilization of the canal waters for purposes of sewage disposal. This project obviates the difficulties arising out of the treaty obligations in so far as the river itself is concerned. To merit consideration, however, it must also remedy the situation in Lake Ontario and must accomplish this result with at least as small a burden of expense and in as satisfactory a manner in all other respects as can reasonably be shown to be the case with the alternative project of river disposal.

CONDITIONS WITH TREATMENT.

The disposal of sewage by dilution in a running stream results under ideal conditions in a practically complete oxidation of the putrescible organic matter, and destruction of sewage bacteria. If conditions permit sedimentation, there is an added effect due to this cause. The natural agencies at work in the stream require time for the completion of the purification, and the deposit of material upon the bed of the stream has the effect of increasing the time element and permitting more perfect purification. This is noticeably the case in Lake Erie, where the sewage of the Detroit district is so completely destroyed as to leave in the center of the lake no trace of its existence. In a canal the situation is somewhat different. Sedimentation results in an initial purification which is only apparent and temporary. The deposited material still makes its demands upon the oxygen supply of the water above and, as in this case the supply is limited and, as the long-time demand of the sludge exceeds many times the shorter time demand of the flowing unsettled sewage, conditions as to physical nuisance are aggravated, not improved, by sedimentation. Thus, while sedimentation assists in the ultimate disposal of sewage, it does so at the expense of the limited oxygen supply of the stream. For this reason the prevention of nuisance in a sluggish stream demands a much greater initial dilution of the sewage than in the case of a rapidly running stream.

In the Chicago Drainage Canal for many miles above the outlet there is during warm weather a condition of complete exhaustion of the oxygen and of foul anaerobic decomposition. Under these conditions further purification by oxidation can not proceed, and it is only when this foul stream is further diluted in the shallower Des Plaines that oxidation by natural agencies is resumed.

With a dilution of 6,000 second-feet, and with velocities of from 1.9 to 2.5 feet per second, such as are indicated in the preliminary plans of the projected drainage canal between Lake Erie and Lake Ontario, and with the present tributary population, sedimentation would take place and local nuisance arise especially in warm weather. Ultimate oxygen exhaustion would probably not occur, so that the discharge into the lower lake would probably not be foul and offensive in a physical sense. In the course of 17 hours, the estimated time of passage from the principal sewer outfalls of Buffalo to the lake, a certain improvement in bacterial content would be noted, but owing to the greater concentration of the sewage, the discharge into the lake would be under far less favorable conditions than at present, with thorough dispersion in the large volume of river water. The resultant pollution of that portion of the lake waters near the point of discharge would be serious, and by reason of the intensity of the pollution, the effect of winds and current would carry undesirable pollution to greater distances and in greater intensity than is now observed. Aside from the possibilities of transboundary effects, the conveying of the sewage of this district in much more concentrated form than at present directly to the shores of Lake Ontario, and at a point outside the main current of the Niagara River, would result in an injury to American riparian and lake interests greater than those now existing. Nor can the possibility be excluded that this more concentrated pollution will at times cross the international boundary.

Thus far the discussion has dealt with present populations. A project of this magnitude can not be entered upon without full consideration of future necessities. With a future population of 1,000,000, conditions as regards lake pollution would be aggravated not only in proportion to the increase, but to a far greater extent because of the overtaxing of the dilution capacity of the canal itself. In such a case there can be no question as to the character of the resultant stream. Throughout the warmer months it would be devoid of oxygen, dark in color, and foul smelling. Its character would be such that some change would be urgently demanded. Further dilution or sewage treatment before discharge into the canal would be the only available remedies. Since the dilution is limited, treatment alone may be considered.

TREATMENT REQUIRED.

The problem presents too many indefinite factors to permit of any exact statement of treatment requirements. It can be stated, however, with assurance that these will not be less than those outlined for the present conditions of river discharge. In the case of the canal interest attaches primarily to putrescible organic matter, which involves the most difficult and expensive form of treatment. In other words, by adopting a canal project, utilization of the purifying capacity of the river upon this material will have been discarded and added responsibility placed upon the lake. The removal of some putrescible matter by

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preliminary sedimentation is possible, but for just how long a period, with increasing population, the canal could continue to complete the work of oxidation of settled sewage and not be overtaxed so as to become itself a sewer can not be determined. The limits are probably between the present population and double that number. Further treatment of organic matter other than by sedimentation involves oxidation upon filters or by some similar process, and under local conditions would be almost prohibitively expensive.

Bacteriologically, there would be some gain in the canal project over the river discharge. The river does not permit sedimentation, and its high velocity carries the sewage bacteria to the lower lake in practically undiminished numbers. In the canal the number of bacteria surviving the passage to the lake would be diminished in the 17 hours' interval, both by sedimentation and by natural decrease. This advantage would be largely offset, however, by the greater concentration of sewage in the canal waters, which would be in the ratio of the river discharge, 210,000 second-feet, to the canal discharge, 6,000 second-feet, or thirty-fivefold. The waters of the canal and of the end of Lake Ontario adjacent to and within an undetermined radius of its outlet would be polluted to nine times as great an extent as the Niagara at present, even after allowing for a 75 per cent decrease in bacteria en route, a maximum estimate. This condition must obviously be met with some form of disinfection treatment, for even though it have no international aspect, an assumption not wholly justified, it assuredly would not be an "advisable" plan in the sense of the reference, unless it could compare in net results accomplished with other plans presented.

To place any canal project upon an equal basis of merit with the plans outlined for treatment and discharge into the Niagara, a minimum treatment equivalent to sedimentation and disinfection of the sewage before discharge into the canal must be added, with no assurance that the result would then be satisfactory.

CONCLUSION REGARDING THE DRAINAGE CANAL PROJECT.

This consideration of a drainage canal project, therefore, leads to the conclusion that such a canal if constructed would present no advantages over the Niagara River as a means of sewage disposal, and that the cities of the Niagara frontier, located upon one of the greatest rivers of the country, need no additional water facilities for the disposal of their sewage by dilution methods. Such incidental purification as is called for in connection with the utilization of the resources of this stream represents the minimum of requirements for any dilution system, and dilution in any smaller volume of water will call for more intensive treatment for an equal degree of protection of health and property.

SUMMARY OF ENGINEERING INVESTIGATION.

TYPE OF TREATMENT.

The general type of treatment adopted, with suitable local modification, is therefore essentially the same in all cases. It comprises coarse screening for the removal of large floating material, sedimentation in Imhoff tanks, with simultaneous chemical disinfection with chloride of lime. The necessary auxiliary plant, sludge drying beds, chemical mixing tanks, etc., are also provided.

COSTS.

The estimated costs of construction have been treated in the usual manner as invested capital against which an annual charge for depreciation based upon an assumed life (sinking-fund allowance) and an interest charge have been made. This annual charge has been increased by the estimated annual operating expenses to give a total annual expense, and this in turn has been reduced to a per capita basis for purposes of comparison. These figures are set forth in detail in the reports which follow. They are summarized in Tables VIII, IX, and X.

TABLE VIII.—*Summary of costs and annual charges for sewage treatment, Detroit district.*

(For details see Tables 17-87).

City.	Population designed for.[1]	First cost.	Annual charges.			
			Fixed.	Operating.	Total.	Per capita.
Detroit, Mich.	950,000	$5,932,024	$294,901	$215,545	$510,446	0.54
	[2]2,631,350	12,905,350	635,016	525,545	[2]1,160,561	.44
Windsor District, Ontario.	55,000	392,286	21,291	16,000	37,291	.68
	[2]110,000	779,187	40,868	25,000	[2]65,868	.60
Port Huron, Mich.	25,000	291,135	15,781	9,000	24,781	.99
	[2]40,000	356,677	19,249	11,000	[2]30,249	.76
Sarnia, Ontario.	16,000	100,250	5,414	6,000	11,414	.71
St. Clair, Mich.	3,000	28,063	1,620	1,200	2,820	.94
Marine City, Mich.	4,000	62,940	3,655	1,700	5,355	1.34
Algonac, Mich.	1,700	14,650	928	1,400	2,328	1.37
River Rouge, Mich.	15,000	63,635	3,204	4,500	7,704	.51
	[2]30,000	115,385	6,105	7,000	[2]13,105	.44
Ecorse, Mich.	4,000	23,078	1,331	1,400	2,731	.68
Ford City, Mich.	5,000	32,287	1,814	1,600	3,414	.68
Wyandotte, Mich.	16,000	68,560	3,911	5,000	8,911	.56
	[2]30,000	101,960	5,714	8,000	[2]13,714	.46
Trenton, Mich.	1,200	2,650	132	500	632	.53
Amherstberg, Ontario.	3,000	17,056	1,079	1,300	2,379	.79
Total.	1,008,900	.....	.....	.....	620,206	.565

[1] For treatment. Interceptor designed for greater populations in practically all cases.

[2] These quantities excluded from the totals and general average per capita charge.

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TABLE IX.—*Summary of costs and annual charges for sewage treatment, Buffalo district.*

(For details see Tables 88–186.)

	Population designed for.[1]	Total first cost.	Annual charges.			
			Fixed.	Operating.	Total.	Per capita.
Buffalo, N. Y.	600,000	$3,598,751	$203,457	$187,411	$390,868	0.648
Tonawanda, N. Y.	11,500	70,685	4,241	6,650	10,891	.947
North Tonawanda, N. Y.	18,000	130,166	7,451	8,900	16,351	.885
La Salle, N. Y.	3,500	38,648	2,320	1,500	3,820	1.091
Niagara Falls, N. Y.	69,000	535,950	30,730	28,457	59,187	.857
Niagara Falls, Ontario	18,000	83,637	5,108	8,960	14,068	.782
Lackawanna, N. Y.[2]	16,342	4,000	240	1,200	1,440	.088
Bridgeburg, Ontario[2]	2,110	2,000	120	500	620	.294
When needed.						
Fort Erie, N. Y.	2,000	13,600	816	1,500	2,316	1.16
Kenmore, N. Y.	2,500	10,000	600	1,500	2,100	.84
Chippawa, Ontario	850	28,050	1,680	520	2,200	2.59
Queenston, Ontario	300	4,300	258	500	758	2.53
Lewiston, N. Y.	900	5,600	336	500	836	.929
Youngstown, N. Y.	1,000	20,000	1,200	500	1,700	1.07
Total	746,002				507,155	.68

[1] For treatment. Collectors designed as for population to be expected in 1950.
[2] Additional to existing treatment.

TABLE X.—*Average annual charge per capita for sewage treatment, Detroit and Buffalo districts.*

	Population.	Total annual charges.	Per capita annual charges.
Detroit district	1,098,900	$620,206	$0.565
Buffalo district	746,002	507,155	.68
Total	1,844,902	1,127,361	.611

The weighted average annual charge for the entire population of the Detroit district is found to be $0.57, for the Buffalo district $0.68, and for the two combined $0.61 per capita per annum. For comparison with this figure it will be of interest and value to determine the total charge for water supply and sewerage in certain cities. Sewage disposal is properly to be regarded as the final step in a complete system which begins with the collection, purification, and distribution of the water supply, includes the collection of domestic and industrial sewage, and ends with the disposal of the sewage. Without water supply there would be no sewage and with water supply, sewers and final disposal are essential. The system, regarded as a whole, is necessary to the well-being of the community; the proper disposal of the final product is a necessary part of the system, and its cost a part of what the community must pay for the benefits of water and sewerage. The statistics of the United States Census Bureau are available for the purpose of this comparison.[1] There are there given the present value and annual operating costs of water supplies and sewerage. In certain cities the cost of disposal is included, but this has been subtracted in the more important cases and the remaining items do not affect the result materially. An arbitrary interest and depreciation rate of 5 per cent of the present value has been used, which gives annual charges that are at least not too high. The tabulated figures follow in Table XI.

[1] U. S. Census Bureau, Financial Statistics of Cities, 1912, Washington, D. C., 1913.

TABLE XI.—*Present value, operating, fixed, and total annual charges of water and sewerage works in American cities. (Weighted average per capita.)*

[Data from United States Census Bureau.]

Cities with population of—	Present value.	Annual capital charge, 5 per cent.	Annual operation.	Total annual charge.
Over 500,000	50.83	2.54	1.44	3.48
300,000–500,000	53.31	2.66	1.35	4.01
100,000–300,000	53.12	2.66	1.26	3.92
50,000–100,000	44.97	2.25	1.46	3.71
30,000–50,000	43.83	2.19	1.46	3.65
All over 30,000	50.92	2.55	1.39	3.94

In comparison with these costs, which are fairly representative, and, because of their number, subject to less error than those of individual cities, the cost of sewage disposal as a part of this total cost of water and sewerage does not appear to be an unreasonable or disproportionate amount.

CONCLUSIONS AS TO REMEDIES.

Application of the criterion of effective dilution to the case of the Detroit and Niagara Rivers has been shown to lead to a certain specified degree of sewage treatment in the two cases. The costs of the required remedial measures have been determined and found to be reasonable in view of the results to be attained, and not disproportionate in view of the general costs of water and sewerage works in American cities. The application of these measures upon these two streams is therefore recommended as both "possible" and "advisable" in the terms of the reference.

Similar studies of cost were also made in the case of the St. Clair River communities upon the same basis of the requirements.

The criterion of effective dilution must also be applied to this and the other boundary rivers to determine what, if any, sewage treatment is required in each case. It is readily seen that except in the case of the Detroit and Niagara Rivers no further treatment is at present required to satisfy the general international requirements as here laid down. The application of the measures outlined for the St. Clair River, for example, which is the next most seriously polluted stream, is not justified by the evidence of transbound-

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ary effect, this stream being in a better condition than that to which it is feasible to bring the Detroit and Niagara Rivers by present-day methods of sewage treatment. This conclusion, however, is of a general nature and must be modified according to each local situation. There must be considered, first, the conclusion of the advisory engineers, that a minimum requirement for discharge of sewage into these waters should be the removal of gross floating material by coarse screens. Treatment to this extent is indicated wholly upon the grounds of the immediate local effect of sewage discharge in a purely esthetic way. In addition to this minimum requirement, there is also to be considered the proximity of near-by waterworks intakes and the question of so dispersing the sewage throughout the volume of the stream that not only the average conditions may comply with a reasonable criterion of purity, but that the concentration of sewage at any one point or in any one line of flow shall not be excessive. On the other hand, local conditions may determine that concentration of sewage near the shore and location of waterworks intakes in the center of the stream represents the most economic solution. These are matters which are primarily of local interest and need not, in the first instance at least, come under the general administrative control over these boundary waters from an international standpoint.

In the development of a systematic policy of stream protection, however, it may very well appear that the future requirement of the situation may be best met by bringing the entire control of stream pollution under one administrative organization. Whatever may be the solution of this matter in the case of those streams which are not at present so polluted as to demand remedial treatment under the terms of the treaty, it is evident that the organization responsible for carrying out this work in general must also be responsible for the making of routine observations upon all the boundary waters with sufficient frequency to permit the establishment of the facts of pollution and of its extent with increasing population, and to indicate the future need of remedial requirements sufficiently in advance of their actual necessity to permit proper engineering studies and the construction of the necessary works. In this sense, therefore, the jurisdiction of whatever administrative body may be appointed to take charge of this work should be coextensive with the entire system of boundary waters. In the case of the St. Clair River, the detailed engineering studies already alluded to have been made with the same degree of care as has been employed upon the more seriously polluted rivers, although, judged solely from the terms of the reference, the application of general remedies is not called for at the present time. These studies, however, have been made to serve a twofold purpose. In the first place the relation of sewage disposal to water supply on either side of the river is one demanding some definite and immediate local consideration, independent of any international questions involved. These lead necessarily to minimum requirements of treatment and can not reduce the local requirements, which are in general more exacting. In the second place, this river probably will be the first of the remaining streams to fall within the limits of effective dilution, and the studies that have been made will serve to point out the requirements of the future toward which drainage studies and allied problems should be directed. Studies of this character are needed and should be made in the near future in the case of all of the other communities upon the boundary rivers. It is worthy of suggestion that in the interest of economy and uniformity of administration, studies along these lines might well be continued by the International Joint Commission or by the administrative organization appointed to deal with this matter. In this way the problems of the future will be more definitely brought to the notice of these communities and their general solution will be better correlated along similar lines.

POLLUTION BY STEAMBOATS—GARBAGE.

Some attention was given in the Progress Report to the matter of steamboat pollution of the boundary waters. This was shown to be a distinct source of pollution to be reckoned with in certain sections. This matter was also dealt with at the conference with the consulting sanitary engineers and their recommendations regarding it have already been quoted. In view of the character of this pollution, steamboats must be looked upon as moving sewer outlets traveling over the boundary waters and necessarily passing at times by and in close proximity to waterworks intakes. While the total contributing population is not great compared with the populations dealt with in the case of the cities, the peculiar conditions under which this pollution is discharged make it highly desirable, if feasible, to deal with this problem. Investigations conducted by the United States Public Health Service at the Hygienic Laboratory, Washington, D. C., have shown the entire feasibility and practicability of thoroughly disinfecting the discharge from steamboats by means of live steam. The apparatus required for this purpose is inexpensive and does not require an undue amount of space. The entire cost of installation and operation of such a disinfecting system is such that it can be borne without difficulty by the owners of steamboats and the placing of this additional responsibility upon these owners is entirely justified by the benefits which will result. The importance of this aspect of the pollution problem is sufficient to justify the application of remedial measures in this case pending the

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adoption of more general measures on the part of the cities. Even under existing conditions the lessened danger to the water supplies of the steamboats themselves, as well as to those municipal supplies which are at present affected only by steamboat pollution, will justify the immediate adoption of these measures.

In the case of one American community, the city garbage and other refuse matter is dumped into one of the main outfall sewers, through which it passes directly to the river front. This material is not only unsightly in the immediate vicinity, but by reason of its gross character it serves to pollute the waters with undesirable organic material the evidences of which persist for many miles. Such a practice is obviously improper and unnecessary and should be specifically prohibited in any regulations governing the pollution of boundary waters.

CONSTRUCTION AND MAINTENANCE OF WORKS.

MEANS FOR SECURING CONSTRUCTION.

The reference further calls for recommendations as to—

> by what means or arrangement can the proper construction or operation of remedial or preventive works or a system or method of rendering these waters sanitary and suitable for domestic and other uses be best secured and maintained in order to secure the proper protection and development * * * of all interests involved * * *.

The reference to means for securing the proper construction of remedial works, if it be not a duplication of the earlier reference to a "way or manner" to remedy or prevent existing pollution, must deal with the necessary legal machinery, or procedure, for carrying into effect the "way or manner" found "possible and advisable." It is not therefore an engineering question and its discussion will not be undertaken at this point.

MAINTENANCE AND OPERATION OF WORKS.

The further reference to maintaining the operation of the remedial works and to the protection and development of all interests involved evidently looks to the future administration of the matters dealt with. Such administration involves engineering and administration features in addition to the legal and legislative and the former will be treated here.

The procedure and experience of the Provinces and States which have dealt with stream pollution in an effective administrative manner may be taken as a guide in this matter. Proper administrative control of stream pollution must be based upon laws so carefully drawn as regards their reasonableness and their consideration of common-law rights as to stand the test of the courts. These laws receive their support in the police power of States to abate nuisances and to protect property and the public health.

The enforcement of the law demands an organization equipped with facilities for engineering and laboratory examinations and investigations and with a staff versed in the principles of public health, sanitary engineering, chemistry, and bacteriology. The particular case under discussion will necessitate an organization of this kind and of considerable size. Its duties will refer largely to the protection of the public health, and in order to prevent duplication of effort and equipment the existing public health organization of the two Governments should be utilized as far as possible. To this end the following is tentatively submitted. A board to be composed of the Surgeon General of the United States Public Health Service and of the Director General of Public Health of Canada might well constitute the head of the administrative organization, utilizing the present quarters and equipment of the marine hospitals in the United States and of any similar facilities in Canada. Following precedents already established by the International Joint Commission, this board might be authorized to formulate rules and regulations for carrying out the recommendations and policies of the commission, such rules as well as any matters upon which the board may not be in agreement to be submitted to the commission for approval or decision.

GUIDING PRINCIPLES IN CONTROL OF POLLUTION.

The following general principles should guide in the formulation of regulations for the control of pollution in the boundary waters in its international aspects:

1. The boundary waters shall not be polluted on either side to the injury of health or property upon the other.

2. In the case of the boundary rivers the interests of the two countries are so closely bound together as to be mutual and the quality of the streams as a whole shall be considered in determining upon limits of permissible pollution.

3. The limit of permissible bacterial pollution shall be deemed to have been exceeded when the effective dilution as hereinafter defined shall be less than 4 cubic feet per second per capita of contributing population, based upon mean river stages during the season May to September, inclusive.

4. The effective dilution shall be taken as the quotient of the actual physical dilution divided by the residual fraction of the total bacteria remaining after treatment, provided that in the case of the St. Lawrence and other rivers where the time element is such as to permit some degree of self-purification between points of successive pollution, this factor shall be con-

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sidered as an element of treatment entering the determination of effective dilution at the lower point.

5. In all cases where the actual stream flow below any one point of pollution is less than 4 cubic feet per second per capita of contributing population, or where the net effect of successive pollution with proper allowance for self-purification in the intermediate stretches exceeds the equivalent of one contributing person per 4 cubic feet per second of stream flow, sewage treatment shall be employed to reduce the net bacterial pollution to a basis of an effective dilution of 4 second-feet per capita, as defined.

6. Sewage treatment, while based primarily upon bacterial pollution, shall also include the removal of suspended solids capable of settling to approximately the same degree as is called for in the case of bacteria; provided that this requirement shall not be extended to an unreasonable degree in the light of good engineering practice; and provided further, that in the case of combined sewer systems, ordinary mineral detritus shall be excluded in computing the degree of removal.

7. In all cases where sewage treatment to a specified degree is demanded, the entire contributory population shall be dealt with upon the same basis of relative improvemnt required, so that the net residual pollution from each community shall be proportional to its population; provided, however, that where the factor of self-purification is an element in the degree of pollution at any point the population above shall be reduced to equivalent population at that point by the self-purification factor, and the burden of responsibility shall be apportioned in terms of these equivalent populations.

8. Steamboats which pass by waterworks intakes shall be regarded as being capable of discharging sewage in the near vicinity of those intakes without appreciable dilution. The application of the rule leads in this case to a complete bacterial purification or sterilization before discharge. Equivalent removal of solids capable of settling will not be required in the case of steamboats.

9. No garbage, city waste, offal, or other like material capable of polluting or rendering offensive the waters shall be deposited in the boundary rivers, or in such places as will permit their reaching these rivers.

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APPENDIX 1.

DETROIT AND ST. CLAIR RIVER DISTRICT.

ENGINEERING STUDIES.
INTERCEPTION AND TREATMENT OF RIPARIAN SEWAGE.

1916.

REPORT OF

H. C. McRAE, District Engineer,
AND
IRVING P. KANE, Assistant Engineer.

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INTRODUCTION.

We have the honor to present a report upon investigations made by the Detroit office relative to remedial measures for the conditions of pollution of the St. Clair and Detroit Rivers.

DESCRIPTION OF DISTRICT.

GEOGRAPHY.

Geographically, the territory considered in this report consists of the border lands lying on both sides of the St. Clair and Detroit Rivers, which, together with Lake St. Clair, form the natural divisions between the Province of Ontario, Dominion of Canada, and the State of Michigan, U. S. A. These waters pursue a general southwesterly course, connecting Lake Huron and Lake Erie. The district may be considered as being divided into two parts by Lake St. Clair. The upper portion is formed by the St. Clair River, which flows for a distance of about 40 miles by steamer track from the extreme southern end of Lake Huron to the northeastern side of Lake St. Clair. The Detroit River, forming the lower part of the district, has its source on the southwestern side of Lake St. Clair, at a point about 17 miles distant from the southwestern end of the St. Clair Flats Canal, and follows a course which is curved for a part of the way for a distance of 31 miles, discharging finally into Lake Erie near its western end.

TOPOGRAPHY.

Topographically, the land of the district is quite flat and relatively low with respect to the water level of the rivers.

ST. CLAIR RIVER.

The St. Clair River is composed of two characteristic sections. The upper normal section is 27 miles long, varies in width from one-fourth to three-fourths of a mile, and contains two islands, namely, Stag Island and Woodtick Island. The banks are clay and sand and are quite steep. The depth, except immediately adjacent to banks, varies from 20 to 47 feet. The lower Delta section divides the river into a number of distributories, and forms what is commonly known as the St. Clair Flats. The largest of the distributories are the North, Middle, and South Channels, the latter being the most important one, and the one used for navigation.

The discharge of the St. Clair River may be given by quoting from the Report of the Chief of Engineers, United States Army, 1912, Appendix FFF, Northern and Northwestern Lakes:

> The flow of the St. Clair River for mean lake levels, 1860–1911, inclusive, by the 1910 equation is 207,750 c. f. s.

The velocity, according to the "1904 Report, Chief of Engineers, United States Army," is 5.561 feet per second for the first 0.8 of a mile, and 3.078 feet per second for the remainder of the distance. These velocities are based on a discharge of 209,450 cubic feet per second.

The water is at most times very clear, but after heavy rains is colored by the clay-bearing discharge of the Black, Pine, and Belle Rivers on the Michigan side. It has been observed on days following heavy rains that opposite St. Clair the line marking the clear water from the colored was very distinct, while a few miles downstream, but well above Algonac, the water presented a nearly uniform appearance from shore to shore. The occurrence of this phenomenon in such a swiftly flowing stream would seem to be strong evidence in support of the contention that pollution crosses the boundary in both the St. Clair and Detroit Rivers.

DETROIT RIVER.

The upper 13 miles of the Detroit River is of fairly constant cross section, except at its head, where it is divided by Peach Island and Belle Isle. The bottom is of earth and the banks for the most part quite steep. The width of the greater part of this section varies from one-half to three-quarters of a mile, and the depth from 25 to 40 feet. The lower part, from the head of Fighting Island to Lake Erie, is broken up by many islands and expanses of shallow bottom, with the bottom consisting of earth and boulders, and in some places of bed rock and boulders.

The discharge of the Detroit River may, with sufficient accuracy for practical purposes, be considered as the sum of the discharge of the St. Clair and the drainage area of Lake St. Clair. The "1904 Report of the Chief of Engineers, United States Army, Appendix EEE," says that the "St. Clair drainage area adds on the average 4,700 cubic feet per second."

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The discharge of the Detroit River is, therefore, 207,750 plus 4,700, or 212,450 cubic feet per second. The following table, made up from information obtained from the report quoted above, shows the velocity characteristics of the different stretches.

TABLE No. 12.—*Velocities in the Detroit River.*

Stretch.	Description.	Velocity, feet per second.
1	Windmill Point to Campau Avenue	1.885
2	Campau Avenue to Fort Wayne	2.447
3	Fort Wayne to Mamajuda	1.720
4	Mamajuda to Ouelettes	1.973
5	Ouelettes to Amherstberg	2.006

Grosse Isle has an important effect on the course of the river in that it directs the major portion of flow close to the Canadian shore for a distance of about 3 miles just above and below Amherstberg. This island by its position also forms what is known as the "back channel," which flows between Grosse Isle and the Michigan shore. This back channel is the most heavily polluted of any of the channels in the lower part of the river. It receives a comparatively small portion of the flow of the river, but on account of the configuration of the bottom, is obliged to carry the pollution from Ecorse and Wyandotte, as well as a major portion of that from Detroit and River Rouge.

LAKE ST. CLAIR.

Lake St. Clair, which forms the middle link of the chain of waters connecting Lake Huron and Lake Erie, has a water surface of over 503 square miles. Over the greater portion, its depth is between 15 and 21 feet. These depths prevail in the central, southern, and southwestern sections, those in the northwestern section near the St. Clair Flats being somewhat less. The bottom is sandy near the shores on all sides, but is clay over a large area in the center of the lake. On account of the shallowness of the lake, strong winds will make the water quite muddy at times. The lake acts as a storage basin with attendant purifying influence on the polluted waters of its tributaries, so that the pollution which is in evidence at the mouth of the St. Clair River partly disappears before the water reaches the entrance to the Detroit River.

INDUSTRIAL CHARACTERISTICS.

Various conditions exist at different localities with respect to industrial development. Along the St. Clair River industrial pursuits are not followed very extensively, although there is some activity at Port Huron and Sarnia and a smaller amount at the communities downstream from these. The same is true of the extreme lower section of the Detroit River, but, on the other hand, the upper section of this river is teeming with activity of a manufacturing nature, the interests focusing at Detroit on the Michigan side and being quite active also at Windsor, Walkerville, and Ford City on the Ontario side. The principal industry of this section is that of the manufacture of automobiles, their parts and accessories. Other important industries include the manufacture of drugs, salt products, stoves, copper and brass products, metal windows, electric heating materials, boats, carbon, beer, and whisky. None of the industrial processes are likely to result in the discharge of waste products in sufficient quantity to seriously affect the condition of the river water, except possibly those of drug manufacture and the concerns depending for their raw material on the immense salt beds which underlie this section. Some of the latter, among which might be instanced the Solvay Process Co., the Michigan Alkali Co., and the Penn Salt Co., discharge quite large quantities of waste products about which there is considerable complaint in certain localities. Among other things, it is averred that fishing has been seriously interfered with. The residents of some of the villages below Detroit are reputed to feel rather keenly about the condition that has been created, many of them having formerly depended on fishing as a part of their source of livelihood. It seems quite likely that this subject of industrial wastes may soon become sufficiently pressing to require detailed investigation and possibly some sort of regulation.

POPULATION.

The population contributing untreated sanitary sewage to the St. Clair and Detroit Rivers is confined largely to a number of municipalities which are listed in Table 13 with their respective populations in 1915.

In addition to the above there is some temporary summer population at the St. Clair Flats (a summer resort on the Delta of the St. Clair River), in some of the towns on the St. Clair River, and in cottages scattered along the rivers at various points.

WATER SUPPLY.

All these municipalities obtain their water supply from the river waters, and in each case they have taken care to locate their waterworks intake above their own sewers. In no case, however, are they afforded any protection against pollution from upstream communities except that of chlorination, which has already been introduced at most of the places. It is worthy of note that Port Huron and Sarnia, the uppermost cities on the St. Clair River, have both taken steps in recent years to purify their supplies, although coming as they do from the St. Clair headwaters they are obviously less contaminated than any other supply in the district.

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TABLE No. 13.—*Population of municipalities on the St. Clair and Detroit Rivers, 1915.*

ST. CLAIR RIVER.

United States side.		Canadian side.		Total.
Municipality.	Population.	Municipality.	Population.	
Port Huron	20,000	Sarnia	11,600	
St. Clair	2,600			
Marine City	3,800			
Algonac	1,200			
Total	27,600		11,600	39,200

DETROIT RIVER.

Detroit	[1] 760,000	Ford City	2,000	
River Rouge	8,000	Walkerville	4,600	
Ecorse	1,800	Windsor	24,000	
Ford City	2,500	Sandwich	2,500	
Wyandotte	10,000	Amherstberg	2,600	
Trenton	1,200			
Total	783,500		35,700	819,200
Total				858,400

[1] Includes some suburbs of the corporate city. This figure is that given by the report of the Board of Water Commissioners for the year ending June 30, 1915. It includes River Rouge, Ecorse, and Oakwood, which lie outside of the area adopted for the Detroit metropolitan district. It, however, does not include the population in the Grosse Point villages, and other scattered communities which are within this area. Everything considered it is believed that the population inside the district is close to the figure given.

ORGANIZATION.

The personnel of the organization conducting the studies with their terms of service was as follows:

H. C. McRae, district engineer, February 15, 1915–April 1, 1916.

Irving P. Kane, assistant district engineer, March 1, 1915–December 1, 1915.

Russell E. Takken, draftsman, March 10–December 1, 1915.

L. G. Lenhardt, draftsman, March 5–December 1, 1915.

The district engineer was responsible for the general conduct of the work and for the treatment plant studies, the assistant district engineer for the interceptor studies and the draftsmen for the compilation of data, detailed computations, and the preparation of the plates. The faithful and energetic services of the members of the office force have contributed largely to the outcome of this investigation, and are hereby acknowledged.

It is a pleasure to record here appreciation of the courtesy of Dr. John W. S. McCullough and Mr. Frederick A. Dallyn, B. A. Sc., respectively, chief health officer of Ontario and provincial sanitary engineer of Ontario, in rendering assistance in the studies for the cities in Ontario.

The Detroit studies were made in close cooperation with Mr. Clarence W. Hubbell, consulting engineer, and his office force, to whom had been referred, on the part of the city of Detroit, certain questions pertaining to the sewerage and sewage disposal problems of that city.

DETROIT, MICH.

METROPOLITAN DISTRICT.

The city of Detroit lies in such a position that it completely separates from the Detroit River the important villages of Highland Park and Hamtramck, as well as other minor but growing communities, which, because of their topographical position, should logically, and actually do, discharge their sewage through Detroit's sewers. One of these villages is now seeking further relief through the medium of litigation. Sewerage needs will soon be pressing also in the part of the Grosse Point section east of that portion which now drains through the Jefferson Avenue sewer to the Fairview pumping station in Detroit. The villages in this section must drain either through Detroit or directly into Lake St. Clair, or indirectly into Lake St. Clair through small, sluggish water courses; and neither of the last two alternatives are satisfactory, nor will they likely be in the future.

Furthermore, so long as the various communities referred to continue to act independently in solving their sewerage problems, it seems certain that there will be friction between them and economic waste, due to duplication of effort and the lack of coordination in planning for future needs. In consequence of the conditions cited, and of the fact that this section is developing and increasing in population very rapidly, it would be illogical to confine a study of the future sewerage problems of this district to the area now included within the corporate limits of Detroit, and such a course would surely be fruitless of concrete results. The establishment of a logical drainage district, termed here for convenience the "Detroit metropolitan drainage district," would be advantageous in—

(1) Preventing disputes between the various interested communities.

(2) Effecting economies and producing more satisfactory conditions generally by means of comprehensive planning.

Such a proposed metropolitan district has therefore been selected as a basis for these studies and has been delimited on plate 2 more or less arbitrarily, but with the following points in mind:

1. The inclusion of all territory that is at all likely to become a part of or drain through the corporate city within the next 50 or 60 years.

2. The limitations of position which might tend to prevent existing corporations from being included in such a district.

3. The exclusion of territory beyond the limits of Wayne County.

This area, consisting of about 74,580 acres, includes the villages of Highland Park, Hamtramck, and the Grosse Point section.

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The natural drainage is for the most part through the Detroit River and its tributaries, River Rouge and Conners Creek. A small section in the northeast corner drains through the Milk River to Lake St. Clair, and a narrow strip near the Wayne County line drains to lakes in Macomb County and finally through the Huron River to Lake Erie, just below the mouth of the Detroit River. The topography provides easy slopes, there being, in fact, one section where the average slope for a distance of 4½ miles is only 2.2 feet per mile. Approximately one-half of the area is less than 45 feet above mean river level, and about one-seventh is less than 65 feet above the same point.

EXISTING SEWERAGE SYSTEM.

The sewerage system of Detroit is a combined system which provides outlets for similar systems in the suburban villages of Highland Park, Hamtramck, part of the Grosse Point section, and other outlying sections.

All sewers larger than terra-cotta pipe sizes are built of a local brick which is quite porous and not very well formed, but which is reputed to possess good wearing qualities. The quality of workmanship is only fair. Main sewers are for the most part built in the parallel streets which run perpendicular to the general course of the Detroit River, into which they all discharge, directly or through the River Rouge. Their discharge is, with one exception, by gravity, and is in many cases through multiple barrel outlets and at a variety of elevations. In no case, however, is the outlet submerged at ordinary river stages. The plan and profile records of sewers constructed in recent years are complete and may be considered accurate, but the records of some of the older sewers are reported to be of doubtful accuracy.

The storm-water inlets are of the catch-basin type so that a large portion of grit from the streets is prevented from entering the sewers.

There is very little territory in the district that can not, from physical reasons alone, have its storm water discharged by gravity. In view of this fact there is one novel but important exception to the general plan that has been followed in laying out the main sewers. Reference is made here to the Jefferson Avenue sewer, 9 feet in diameter, the discharge of which is pumped at the Fairview pumping station. This station is a large one, located about 2,000 feet downstream from the water-supply intake crib and is designed to pump all the drainage, both sanitary and storm water, from the locality served by the Jefferson Avenue sewer. This district includes a small section of the eastern portion of the city and a part of the Grosse Point section east of the present city limits. The purpose of this arrangement was the protection of the water supply from polluting drainage which might otherwise have been discharged in the vicinity of the water intake, either directly into the Detroit River or indirectly through Conners Creek.

PROPOSED MODIFICATIONS.

Because of the protective influence of natural currents, it is a mooted question whether the discharge from Conners Creek ever becomes so intermingled with the waters of the Detroit River as to contaminate the present source of water supply. Nevertheless there appears to have been sufficient reason for the establishment of the Fairview pumping station, at least so far as the diversion of the sanitary sewage is concerned. Whether a necessity has existed in the past for pumping the storm water is perhaps an open question, but there is no doubt that the extension of the present protecting measures of pumping both sanitary and storm-water drainage so as to include all of the rapidly growing Grosse Point villages would be prohibitively expensive. It would be better to move the existing water intake to a more distant location in Lake St. Clair. It has therefore been assumed in these studies that the Jefferson Avenue sewer can in the future be used solely for conveying sanitary sewage from the section now served by it, as well as the remainder of the Grosse Point section, and that the storm water from this section will be discharged through other drains into Lake St. Clair, Conners Creek, and the Detroit River. This can be accomplished for the most part by gravity, though there is a small section which will require low-lift pumping.

It will also be highly advantageous if, in future developments the storm-water needs of the territory not now provided for be taken care of by large drains constructed for this purpose, preferably in the Conners Creek and Rouge River valleys, and if this territory be provided with collecting systems designed to carry only sanitary sewage.

There appear to be attractive possibilities in a project for covering over, and straightening the course of, the lower reaches of Conners Creek. This would provide an outlet following natural drainage lines for the storm drainage from an extensive area, and would permit the utilization of considerable land now unserviceable. This land might be used for park purposes, or the returns from the enhancement of its value as a result of the improvement might be used to cover a part of the expense. Such an improvement would also provide an outlet for the effluent of a treatment plant on Conners Creek at practically no additional expense.

POPULATION.

The recent rate of growth of the Detroit district has been so exceedingly rapid that it is difficult to make a forecast which can be relied upon with any

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degree of certainty, for it is hardly possible for such rapid growth to be continued for very long. This community has enjoyed an unusual development in company with the rapid increase of the motor car industry, and, while this industry will no doubt contribute largely in the future toward a healthy growth, it does not seem likely that it will itself grow, in the future, at as high a percentage rate as it has in the past. On the other hand, there are numerous other industries which will contribute substantially to the further development of the district, such as the manufacture of drugs, stoves, and salt products. These are now large, and the last certainly will increase rather than diminish, for the reason that it is founded on a great natural resource of the district. Furthermore, there are apparent advantages of location in the existing and proposed railroad traffic connections with the East and West, the water connection with northern iron ore fields, and proximity to Canadian territory on the natural traffic line from the West to eastern Canada. These factors all point to the conclusion that the past growth and development has rested on solid foundations, and the prediction that future development will be substantial.

The population records that are available are complete. They consist of annual censuses of the water board which check with the United States Census figures every 10 years, so that they may be considered sufficiently accurate for all practical purposes, and from them the plot of plate 3 has been prepared, the solid portion representing the growth in population from 1860 to 1915 and the dotted portion the forecast of future growth.

This plot is of value in that it assists in the forming of a proper conception of the magnitude of projects now under consideration, but for the purpose of sewer design it was necessary to determine upon a probable distribution of population, or, in other words, a probable density of population for the different parts of the district. It is well known that the density of population varies greatly over the area of a large city, being affected by various factors, such as the localization of industrial activities and commercial centers and the characteristics of the dwellers in the various sections. It may be said in general that the residential sections have been developed in a manner typical of many western cities, in that a large percentage of the dwelling houses are detached houses surrounded by ample lawns and numerous shade trees. In the study of population density a large number of house counts were made on known areas in sections that seemed to be representative of various types of development. It was found also that the report of Barclay Parsons & Klapp on the rerouting of street cars contained a very careful study of population distribution, and this was freely consulted. After careful consideration of all the evidence available, it was decided to assume for the purpose of sewer design that the area would be built up ultimately to densities as indicated below.

	Persons per acre.
Section bounded by the Detroit River, Fourth Street, Grand Boulevard, and Jos. Campau Avenue	80
Section bounded by the Detroit River, Jos. Campau Avenue, the northern city boundary line, and Seminole Avenue	60
Section bounded by the Detroit River, Fourth Street, Grand Boulevard, and Eighteenth Street	60
Section bounded by the Detroit River, Seminole Avenue, the northern city boundary line, and St. Jean avenue	50
Section bounded by the Detroit River, Eighteenth Street, the northern city boundary line, Livernois Avenue, and Artillery Avenue	50
Section bounded by Grand Boulevard, the northern city boundary line, Livernois Avenue extended, Joy Road, and Jos. Campau Avenue	50
Section bounded by the Detroit River, Artillery Avenue, Livernois Avenue, the northern and western city boundary line	40
Section bounded by the Detroit River, St. Jean Avenue, and the northern and eastern city boundary line	40
Sections lying outside of those described above	30
Industrial areas within any of the above sections	30

AREAS.

The total area of the district outlined on Plate 2, as stated previously, is approximately 74,580 acres. In Detroit, as in all large cities, certain sections are given over almost entirely to industrial uses, and other sections are similarly given over to commercial uses. Taking the present city of Detroit as sufficiently representative of the proposed district, an industrial map was studied and computations were made to determine upon a reasonable percentage of the total area to allow for industrial development. It appeared that about 20 per cent of the area should be allowed for this purpose. This is in fair accord with conditions in other cities, and was therefore adopted. Furthermore, certain areas were definitely delimited on working maps in that portion of the district which has already developed sufficiently to render such a procedure reasonable.

There was little guiding evidence available for the delimitation of a commercial area, but for the purpose of definiteness an area of 500 acres centering around the present commercial section of the city was adopted.

WATER CONSUMPTION.

All the water used by Detroit and the suburbs supplied by the city is pumped from the Detroit River. The pumping station is located on East Jefferson Avenue near Pennsylvania Avenue, and draws water through a tunnel from a crib which is located just off the head of Belle Isle. The sixty-second annual report of the board of water commissioners for the

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year ending June 30, 1914, lists the following suburban villages as being supplied with water from the Detroit supply: Highland Park, River Rouge, Ecorse, Hamtramck, Oakwood, Grosse Point, and Greenfield. Highland Park now has its own supply. Careful records of the amount of water used have been kept since 1880, and hourly pumpage records are available since 1900. From these records and from the meter records of the water supplied to the various villages it is possible to compute accurately the per capita consumption for the city of Detroit. This figure furnishes the best available information upon which to base estimates of the quantity of sewage to be expected from the district. These data have been set forth in Table 14.

TABLE No. 14.—*Water consumption in the city of Detroit.*

Year ending June 30—	Gallons consumed per capita per day.	
	Average daily rate.	Maximum hourly rate.[1]
1900-1901	165.3	298
1901-2	163.6	287
1902-3	161	256
1903-4	178.4	302
1904-5	173	305
1905-6	161.8	263
1906-7	168.2	262
1907-8	169.4	269.5
1908-9	169.1	292
1909-10	179.3	305
1910-11	180.3	312
1911-12	191.3	287.5
1912-13	179.4	305.5
1913-14	179	281

[1] Detroit and suburbs supplied by the city supply.

An inspection of this table shows that during the years 1900 to 1909, inclusive, the per capita consumption varied considerably, but in only one year did it exceed 173 gallons. The unusually cold winter of 1903–4 is a very probable explanation of the high consumption of 178.4 gallons for that year.

During the later years the per capita consumption has been on a distinctly higher level, but only in one case, that of the year of 1911–12, has it been appreciably over 180 gallons. The winter of 1911–12 was again a severe one, which accounts for the consumption of 191.3 gallons in that year. The increase of the level which has been maintained since 1910 was probably the result of a quickening of industrial activity, with its correspondingly greater percentage draft on the total supply.

Beyond the natural tendencies of the American people toward waste and lavishness, there seems to be no reason to suppose that the per capita rate of water consumption of this district will increase much more, and in view of the fact that several years ago the average consumption was reduced to the extent of about 25 gallons per capita by a campaign of rigid inspection it seems reasonable to assume that the future consumption can readily be kept as low as 190 gallons per capita. This assumption is further supported by the probability of an automatic deterrent against waste being introduced in the form of an increased cost of water. A daily water consumption of 190 gallons per capita has therefore been adopted as a basic figure for use in determining the amount of sewage to be expected from the district.

OTHER FACTORS AFFECTING QUANTITY OF SEWAGE.

In arriving at an estimate of the quantity of sewage contributed by a large community such as the Detroit district, it is necessary to consider certain factors besides population and public records of water consumption. Specifically the factors referred to that are most common, and which were considered in this case, are:

1. The use of water from private supplies.
2. The amount of water pumped that is not returned as sewage.
3. Infiltration of ground water into sewers.

Careful inquiry developed the fact that private well supplies in Detroit are practically nonexistent. There remained the probability of private supplies pumped from the river. These would naturally be supplies of industrial plants, and for the most part used for industrial purposes. It was found that some such supplies do exist, and also that in some cases the industrial discharge was through private drains directly to the river. It was concluded, therefore, that inasmuch as all industrial discharge could readily be made directly to the river, the matter of private supplies might be eliminated from consideration.

The amount of water lost during its course from the source of supply to its discharge into the sewers is not readily determined. There did not appear to be any local data which would throw light on this subject, and after a study of the literature it was decided to base calculations on the assumption that 10 per cent of the total amount of water delivered by the pumps was lost through industrial and commercial processes, and 5 per cent was lost through domestic channels.

The amount of water which enters sewers by infiltration is, of course, extremely variable, both as to time and locality. Over a great deal of the area of the Detroit district it is probably less in quantity and more uniform in rate of entrance than in many places, on account of the nature of subsurface conditions. A large portion of the area under consideration, particularly that portion on which the present city is built, is underlaid with a blue clay, which is very stiff and quite impervious to the passage of water. Some

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sections are of a somewhat sandy nature. It was decided to make an allowance in these studies of 500 gallons per acre per day in the clay sections and 1,000 gallons per acre per day in the sandy sections.

The several factors above referred to having been determined, there remained the consideration of two other important factors in order to permit the calculation of the rate of sewage flow at any particular point. These are the effects of industrial development and commercial development. It is well known that areas devoted to the pursuit of industrial and commercial enterprises contribute much more sewage than other areas of equal extent. Fortunately the water used for these purposes in Detroit is practically all metered, and the meter records were therefore carefully studied to throw light on this matter. It was found that about 35 per cent of the water used was used by industrial and commercial consumers. Furthermore, tabulation was made of the water used by and the area covered by a number of typical industrial plants, and this disclosed the fact that there might be expected an average contribution of sewage of 8,000 gallons per acre per day from areas of an industrial nature in excess of the domestic sewage from that area, based upon resident population. A similar study of commercial areas indicated an average excess contribution of about 33,000 gallons per acre per day.

QUANTITY OF SEWAGE AND BASIS OF DESIGN.

The above conclusions in regard to the quantity of sewage to be expected from various sources have been arrived at for the purpose of determining on a rational basis of interceptor design. With the same purpose in mind they have been brought together and their application in these studies indicated as follows:

Water consumption assumed, 190 gallons per capita per day.
Percentage used for industrial and commercial purposes, 35.
Assumed loss, 15 per cent, of which 10 per cent of 190 or 19 gallons per capita per day is lost through industrial and commercial channels, and 5 per cent of 190 or 9.5 gallons per capita per day is lost through domestic channels.
Percentage of total water supply of the city returned as sewage through industrial and commercial channels, 25.
Percentage of total water supply of the city returned as sewage through domestic channels, 60.
Gallons per capital per day returned as sewage through domestic channels, $190 \times 0.60 = 114$.
Gallons per acre per day from industrial areas in excess of residential domestic contribution, 8,000.
Gallons per acre per day from commercial areas in excess of residential domestic contribution, 33,000.

The amounts given above are average figures for the full 24 hours of the day. The draft of a city on its water supply, and consequently the resulting sewage flow, is far from uniform, and intercepting sewers have to be designed to meet the needs of a maximum flow which will at times be much in excess of the average flow. In order to make proper allowance for the maximum rate of flow, it has been considered that when the maximum rate occurs in the large interceptors the flow (1) from domestic sources will be at twice the average rate; (2) from industrial and commercial sources will be at one and one-half times the average rate.

To illustrate, the maximum rate of flow of sewage at a given point has been determined by adding together: (1) The product of the contributing residential population and 114×2 [1]; (2) the product of the contributing industrial area in acres and $8{,}000 \times 1.5$; (3) the product of the contributing commercial area in acres and $33{,}000 \times 1.5$; (4) the product of the contributing area in acres and 500 or 1,000, according to local subsoil conditions.

In addition to the above the following criteria were used in determining the size of sewer sections:

N in the Kutter formula=0.015 for brick sewers in tunnel.
N in the Kutter formula=0.013 for concrete sewers in open-cut construction.
N in the Kutter formula=0.013 for pipe sewers.
Minimum allowable velocity under maximum-flow conditions, 2.5 feet per second.
Minimum allowable velocity under minimum-flow conditions, 1.5 feet per second.
Sewers to flow full under maximum-flow conditions.

TREATMENT SITES.

The general layout of the existing sewers, coupled with topographical features of the district, suggest that any logical plan for interception and treatment of sanitary sewage will involve intercepting sewers aproximately parallel to the Detroit River and treatment sites on or near the Detroit River, Conners Creek, or the River Rouge, or below the River Rouge. A field inspection developed the fact that there are unoccupied areas of suitable extent near the existing Fairview Pumping Station and at the intersection of Conners Creek and Mack Road, in the eastern portion of the district; at the Fort Wayne Military Reservation, and various points along and below the River Rouge in the western section. In addition there are small areas suitable for screening treatment at the foot of Orleans Street and at the foot of Twenty-fourth street, the first being in the eastern and the second in the western section. With these sites in mind a number of projects have been outlined for study, two of which, one involving sedimentation treatment and the other involving treatment by fine screens, have been adopted for tentative cost studies as offering possibilities of satisfactory and economical solutions. Detailed cost estimates of these two projects have been prepared for presentation.

[1] In some cases where the contributing district and the quantity of sewage were small a factor greater than 2 has been applied.

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DESCRIPTION OF PROJECTS.

Altogether five projects have been considered in these studies. All except project 1 have in common a system of intercepting sewers for transporting the sewage to one or more treatment plants. Projects 2, 3, and 4 include treatment provision consisting of grit chambers, Imhoff tanks, sludge beds, disinfection, etc., and pumping stations where needed, while project 5 contemplates the use of fine screens instead of sedimentation tanks. Project 1 differs from the others in that it calls for a large number of treatment stations along the river front and substitutes for the intercepting sewers a force main, the purpose of which is to transport the sludge from settling tanks to a common point for digestion and subsequent disposal.

PROJECT 1.—UNDERGROUND SEDIMENTATION TREATMENT PLANTS.

This project was studied with three objective points in mind, namely, the avoidance of extensive interceptor construction, the treating of fresh rather than stale sewage, and the avoidance of concentrating large quantities of sewage at a few points. Theoretically, the plan contemplates a sedimentation tank near the end of each sewer outlet. Probably a more practical arrangement from economic reasons would include provisions for short collecting sewers between nearby outlets so that the number of plants might be reduced. As suggested above, the plan includes the following main features:

1. Sedimentation tanks with pumps for collecting the settled matter at fixed points.
2. A system of suction pipes for the constant or nearly constant removal of the sludge in dilute form, probably with 1 or 2 per cent of the total flow.
3. Pumps for the removal of the sludge.
4. Force mains to convey the sludge to an outlying point or points for digestion and disposal.
5. Digestion tanks, drying beds, etc.

Although no detailed cost estimates were made, this plan was considered carefully and was abandoned for the following reasons:

1. Doubt as to the efficacy of sedimentation devices placed in the flow lines of sewers subject to the variable submerging influence of river levels.
2. Doubt as to success in maintaining supporting velocities in suction pipes without an unduly complicated operating schedule.
3. General undesirability of tearing up the streets for extended periods for construction purposes.
4. Increased danger of explosions from gas accumulations due to mutliplicity of points where such occurrence would be possible.
5. Probability that any saving effected in first cost would be overbalanced by the increased operating cost which would be entailed by reason of the multiplicity of treatment stations.

PROJECT 2.—SEDIMENTATION TREATMENT PLANTS AT FORT WAYNE AND ON CONNERS CREEK.

Under this project there would be a plant at Fort Wayne, which would treat the sewage brought to it by a long river front interceptor serving the Grosse Point territory, the portion of the city proper below Warren Avenue in the east and below Myrtle and Otis streets in the west, a short low level interceptor serving the Delray and Woodmere sections, and a high level system with a large branch in Otis and Myrtle streets, and another in Joy Road. The river front and River Rouge interceptors would be at levels such that pumping would be required, but the high level would discharge by gravity.

There would also be a plant at Conners Creek and Mack Road which would treat the sewage brought to it by a main gravity interceptor in the valley of Conners Creek. This Conners Creek interceptor would serve the portion of the Conners Creek watershed which is included in the district limits and above Warren Avenue. It would have two or three small branches to the east and two large ones to the west of the creek, one in Warren Avenue and one branching off near the Forest Lawn Cemetery.

PROJECT 3.—SEDIMENTATION TREATMENT BELOW THE CITY.

This project contemplates a plant between the village of River Rouge and the Detroit River, or between the villages of River Rouge and Oakwood, or possibly inside the city limits near the point where Jefferson Avenue crosses the River Rouge. This plant would receive sewage from a long low-level interceptor along the river front and, as the district developed, from some system of interceptors on a higher level which have their general course either parallel to the Detroit River or diagonally through the district, diverging from the river as they reached their farthermost limits.

PROJECT 4.—SEDIMENTATION TREATMENT PLANTS AT FAIRVIEW, FORT WAYNE, AND ON CONNERS CREEK.

This project calls for treatment plants at Fairview, Fort Wayne, and on Conners Creek. The Fairview plant would receive sewage from a low-level interceptor starting at Orleans Street, shown in profile on Plate 7, and an interceptor serving the Grosse Point section which would be provided by transferring the existing storm-water sewer at East Jefferson Avenue to a separate sewer and extending it as needed to the county line. This arrangement, as suggested elsewhere, would be accompanied by the gradual abandonment of the present practice of pumping large volumes of storm water at the existing Fairview pumping station. The plant at Fort Wayne would receive sewage from a low-level interceptor along the river front from Riopelle Street, as shown on Plate 5, a low-level interceptor serving the Delray and Woodmere sec-

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tions, termed the River Rouge interceptor, shown in profile on Plate 5, and a high-level system with two important branch interceptors, one in Myrtle and Otis Streets, shown in profile on Plate 6, and one in Joy Road. The last named would discharge to the plant by gravity, but the two low-level interceptors would require pumping stations to lift the sewage to the treatment level. The Conners Creek plant would receive sewage from interceptors as described under project 2.

PROJECT 5.—FINE-SCREENING TREATMENT PLANTS AT FAIRVIEW, ORLEANS STREET, TWENTY-FOURTH STREET, FORT WAYNE, AND ROLLIN AND JUNCTION STREETS.

This project calls for interceptors as described under project 4, except that the two low-level interceptors there described would be replaced by six shorter lines, which would feed the first four of the above-mentioned treatment sites. The fine-screening plants mentioned are intended to serve the same territory as the Fairview and Fort Wayne sedimentation plants described under project 4, and additional future treatment plants could be provided as under project 4 or by the establishment of a number of screening stations at such points as future developments would indicate to be suitable for the purpose.

RELATIVE ADVANTAGES AND DISADVANTAGES.

A study of the general features of projects 2, 3, and 4 reveals that each possesses certain advantages and disadvantages which are presented below:

PROJECT 2.

Advantages with respect to project 3:

1. Considerably less cost in sewer construction.
2. Considerably fresher sewage to be treated.
3. Considerably less sewage to be pumped.
4. Less concentration of sewage at one point.

Disadvantage with respect to project 3:

There is no apparent disadvantage, unless it be that the treatment plants would be located nearer the center of population. This is believed to be no great disadvantage in this district.

Advantages with respect to project 4:

1. Plants are all located in territory not now of high-class development.

Disadvantages with respect to project 4:

1. Considerably more cost in sewer construction.
2. Greater concentration of sewage at one point.
3. Older sewage to be treated.
4. More pumping; sewage from Grosse Point would have to be pumped twice—once at Fairview and once at Fort Wayne.

PROJECT 3.

Advantages with respect to projects 2 and 4:

1. Sewage would all be carried below the city for treatment. This advantage is doubtful on broad considerations, for the reason that in any event it would not be removed from proximity to territory which would soon be occupied by home builders.

Disadvantages with respect to projects 2 and 4:

1. Considerably more cost in sewer construction, especially as compared with project 4.
2. Older sewage to be treated.
3. More sewage to be pumped.
4. Very great concentration of sewage at one point; ultimately that of between two and three million people.

PROJECT 4.

Advantages with respect to projects 2 and 3:

1. Considerably less cost in sewer construction.
2. Fresher sewage to be treated.
3. Less sewage to be pumped.
4. Less concentration of sewage at any one point.

Disadvantages with respect to project 2:

One plant in a section which is of a higher class of development.

Disadvantage with respect to project 3:

Plants located nearer the center of population.

PROJECT 5.

This project possesses the same advantages and disadvantages as project 4.

From a survey of the comparative advantages and disadvantages of these projects it becomes apparent that projects 4 and 5 present the important and distinct advantages of less first cost, less pumping cost, less concentration of sewage, and fresher sewage to be treated, with only the disadvantage of having treatment plants located close to residence property; one, that at Fairview, being adjacent to a high-class development. This objection is at the most one of degree rather than of kind, as it would be extremely expensive for this district to select a disposal site or sites so situated that they would not soon be approached closely by home builders. In fact, this Detroit district appears to be a good example of a community where the question of sewage treatment should be faced squarely and attacked from the viewpoint of planning on plant design and operation of such a nature that the usual nuisance-producing conditions will be effectively combated. Projects 4 and 5 have been selected, therefore, for detailed study as to cost of construction and operation.

DETAILED DESCRIPTION OF PROJECT 4.

Project 4 is outlined in its main features on plate 2 and consists of three subprojects, Fairview, Fort Wayne, and Conners Creek, each focusing at a separate treatment plant. The first two of these only will need to be constructed at once in order to provide for the needs of the immediate future.

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FAIRVIEW SUBPROJECT.

The Fairview subproject contemplates a treatment plant near the existing Fairview Sewage Pumping Station, which will receive sewage from—

1. An east low-level interceptor beginning at Orleans Street and following Franklin Street to Walker Street, thence to East Jefferson Avenue, to Park View Avenue, to a proposed pumping station located near the treatment-plant site, where the sewage will be lifted to the treatment level. This interceptor is shown in profile on plate 7.

2. The existing East Jefferson Avenue sewer, which now follows East Jefferson Avenue from the point marked "A" to the existing Fairview pumping station.

The east low-level interceptor described above will be required for immediate needs. The East Jefferson Avenue sewer is already built, and it is contemplated that it will eventually be extended along the shore of Lake St. Clair to the Wayne County line, and have a branch extending up the Fox Creek valley; and that the existing Fairview pumping station will be available for pumping the sewage from this district to the treatment level.

It will be necessary in the development of this project to convert the Jefferson Avenue sewer into a sanitary sewer at some future time by the gradual removal of storm-water connections. The lack of such conversion in the immediate future will, however, not interfere at all with the immediate development, as the present sanitary sewage in this sewer can be pumped to any treatment plant at the Fairview site by the existing pumping station.

FORT WAYNE SUBPROJECT.

The Fort Wayne subproject contemplates a treatment plant located on the river frontage portion of the Fort Wayne Military Reservation, which will receive sewage from—

1. A west low-level interceptor beginning at Riopelle Street and following Franklin Street to St. Antoine, thence to East Jefferson Avenue, to Griswold Street, to Fort Street, to West Grand Boulevard, to West Jefferson Avenue, to a proposed pumping station located near the treatment plant site, where the sewage will be lifted to the treatment level. This interceptor is shown in profile on plate 5.

2. A River Rouge interceptor, beginning at Woodmere Avenue and following Dearborn Avenue to West Jefferson Avenue, to the pumping station mentioned above. This interceptor is shown in profile on plate 5.

3. A west high level interceptor, beginning at Canfield Avenue and following Russell Street to Willis Avenue, thence to John R. Street, to Woodward Avenue Terrace, to Parsons Street, to Cass Avenue, to Brainard Avenue, to Trumbull, to Myrtle, to Michigan Avenue, to Otis Street, to Livernois, to Dix Avenue, to Artillery Street, to the treatment plant. This interceptor is shown in profile on plate 6.

The west low level, River Rouge, and west high level interceptors, as described above, will be required for immediate needs. It is contemplated that the River Rouge interceptor will ultimately be extended to completely serve the westernmost drainage area shown on plate 2, and that the west high level system will be extended to include a short branch on Desmond Street and a large branch up Livernois Street to Joy Road, which will serve an area north of Otis Street and west of Livernois Street and provide an outlet for a higher level interceptor in Joy Road.

CONNERS CREEK SUBPROJECT.

The Conners Creek subproject is intended to provide for future requirements. It contemplates a treatment plant at the intersection of Conners Creek and Mack Road, which will receive sewage from a main interceptor in the valley of Conners Creek. This Conners Creek interceptor will have two or more branches to the east (which are not shown on plate 2 on account of meagerness of field data) and two large branches to the west which are—

1. An east high level interceptor beginning at Bellevue Avenue and following Ferry Avenue to Field Avenue, thence to Canfield Avenue to junction with the Conners Creek interceptor.

2. An interceptor termed the Forest Lawn interceptor, which will begin as shown on plate 2, near the Wayne County line, and run south parallel to Woodward Avenue to a point just below the present city limits, from whence it will run east and discharge into the Conners Creek interceptor near the Forest Lawn Cemetery.

It is contemplated that this subproject will be one that will be subject to a gradual development over an extended period of years. The first step in such development will be the construction of the east high level interceptor for the purpose of relieving the east low level interceptor from crowding, which will occur probably sometime between 1920 and 1930.

The scheme presupposes a discharge outlet in the form of a storm water drain in the Conners Creek Valley, which has been suggested elsewhere as a desirable feature in the development of a comprehensive drainage plan for handling storm water run-off.

CAPACITY OF INTERCEPTORS.

Table 15 shows the capacities of intercepting sewers which are required for present needs, together with their tributary population, the relation between the estimated average and maximum flow, and the maximum flow per capita.

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TABLE No. 15.—*Quantity characteristics of intercepting sewers under conditions of ultimate development, Detroit, Mich.*

Interceptor.	Estimated population.	Estimated sewage flow.		Ratio of maximum to average.	Maximum rate gallons per capita.
		Average M. G. D.[1]	Maximum M. G. D.[2]		
East low level	214,679	33.54	61.22	1.83	285
West low level	237,311	63.20	106.90	1.69	450
West high level	660,053	110.04	196.37	1.78	298
River Rouge	181,336	35.17	60.60	1.72	334
Total	1,293,379	241.95	425.09		
Average				1.76	329

[1] These figures are based on the assumption that infiltration occurs at a uniform rate.

[2] M. G. D.—million gallons per day.

From this table it can be seen that the design assumption has resulted in liberal per capita allowances. The question of inclusion of storm flow was considered, with the conclusion that the above provisions were sufficiently large. The times will be rare when a combination of conditions will obtain, in the absence of storm, that will cause the maximum flow for which provision has been made.

An inspection of the maximum hourly rate of water consumption given in table 14, together with the maximum rates of sewage flow for which provision has been made as shown in table 15, is illustrative of this when consideration is taken of the fact that such high hourly water-consumption rates occur very infrequently, usually only during very hot or very cold weather. It follows, therefore, that during most of the time the interceptors will be capable of carrying storm water in amounts of from 25 per cent to something over 100 per cent of the average amount of sewage. Table No. 16 shows the capacity of the interceptors to carry off storm water when the average amount of sanitary sewage is flowing.

TABLE No. 16.—*Capacity of interceptors for storm water, Detroit, Mich.*

Interceptor.	Capacity, C. F. S.[1]	Average flow C. F. S.	Drainage area in acres.	Excess capacity.		
				C. F. S.	C. F. S. per acre.	Inches per acre per hour.
East low level	95	52	4,220	43	0.0102	0.010
West low level	165	98	4,710	67	.0142	.014
West high level	303	170	16,830	133	.00792	.00784
River Rouge	94	54.5	4,990	39.5	.00792	.00784
Total	657	374.5	30,750	282.5		
Average					.0092	.0093

[1] Cubic feet per second.

An inspection of this table indicates that the interceptors will be capable of taking on the average a run-off of about 0.01 inch per hour, which is approximately equivalent to 0.02 inch per acre per hour precipitation.

Considering the average absorptive power of a city area of the Detroit type, it seems conservative to say that on the average at least 0.03, and possibly 0.04 or more inch of rain will fall per hour without producing appreciable run-off unless the precipitation is continued for a long time. It follows, then, that little or no sewage will overflow diversion dams during the hours in which not more than 0.04 to 0.05 inch precipitation occurs. A study of the rainfall statistics of Detroit for 1914, which year is fairly representative of average conditions, shows that there were—

Six hundred and fifty-eight hours in which it rained or snowed 0.01 inch or more.

Four hundred and fifty hours in which it rained or snowed 0.02 inch or more.

Three hundred and two hours in which it rained or snowed 0.03 inch or more.

Two hundred and eighteen hours in which it rained or snowed 0.04 inch or more.

One hundred and fifty-eight hours in which it rained or snowed 0.05 inch or more.

Seventy hours in which it rained or snowed 0.1 inch or more.

Considering this data in connection with the previous conclusions, it is evident that there will be little or no overflow except during 158 to 218 hours in a year; and assuming that all sanitary sewage will overflow during these hours, it follows that there would be lost annually from 1.8 to 2.4 per cent of the total sanitary sewage. It seems fairly conservative, in consideration of the above argument, to say that the interceptors as designed will intercept annually all but approximately 2 per cent of the sanitary sewage. Furthermore, from consideration of the relative volumes of sanitary and storm-water sewage in time of storm, it is evident that the additional expense of providing interceptor capacity sufficient to care for any great proportion of the above-mentioned 1.8 to 2.4 per cent would not be warranted under the existing circumstances.

COST OF CONSTRUCTION NECESSARY TO COLLECT AND TREAT THE SEWAGE OF THE PRESENT CITY, PROJECT 4.

It has been assumed that five years' time would be consumed before construction could be advanced sufficiently to place treatment works in readiness for operation. Therefore the population on which estimates for the "present city" are based is that expected in 1920, which, according to the population forecast on plate 3, is 950,000.

Before preparing complete estimates of cost of the different parts of the work, the main fundamental items such as brick masonry, concrete masonry, and excavation were studied in the light of local conditions and data, as well as experience in other places. In a number of cases quotations on materials and

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mechanical equipment were obtained. The following unit figures have been used in preparing estimates:

Brick masonry, per cubic yard	$12.00
Concrete masonry, plain, per cubic yard	$8 to 10.00
Concrete masonry, reinforced, per cubic yard	$12 to 14.00
Partitions in Imhoff tanks, per square yard	1.75
Excavation in tunnel, per cubic yard	3.50
Excavation in the mass and in open cut, per cubic yard	75 cents to 1.50
Repaving, per square yard	1.50
Standard castings, per ton	40.00
Special castings, per ton	100.00

COST OF INTERCEPTORS.

The unit prices given above are for the most part in fair accord with the cost of similar work in many other localities. An exception which might be commented on is that of tunnel excavation, which is considerably lower than prices that are often paid for tunnel work. The explanation lies in the fact that most of the tunnel work is done in a peculiar stiff clay, carrying little water and of such a nature that the work can be carried on with practically no timbering. It is common local practice to excavate ahead of masonry work for one shift and then follow up immediately with the masonry. In this way it is possible to do tunnel work much more cheaply than it can be done in most localities.

The price of $12 per cubic yard used for brick masonry is somewhat higher than that usually paid in Detroit on sewer work. The higher price has been used because for this work it has seemed desirable to provide for the use of a better quality brick and better workmanship than current local practice requires.

For convenience in estimating the cost of interceptors the above units for masonry and excavation were used in building up cost figures per linear foot of sewers of different sizes, the average depth of excavation being used for this purpose in the case of sewers to be constructed in open cut.

The low-level interceptors have been located farther back from the river than they might have been for the following reasons:

1. They can thus be built at a higher elevation, and therefore the pumping lift will be reduced.

2. The number of tide gates required to prevent the diversion of river water into the interceptors is thereby reduced.

3. The west low-level interceptor can thus be kept out of the street over which elevated railroad tracks run.

4. They can thus be kept in wider streets, so that their construction will be less likely to cause existing buildings to settle.

5. By being farther from the river, there will be less likelihood of encountering trouble during construction from water and old bulkheads.

This procedure has made it necessary to include in the estimates the cost of small separate collecting systems to handle the sewage, which would otherwise be discharged into the main sewers between the river and the proposed interceptor lines.

It was also thought proper to make provision for a small collector system below the line of the west high-level interceptor, the purpose being to guard against very small amounts of sewage being discharged into the large existing sewers at points of no flow immediately below the interceptor.

These items appear in the following tables, which give the cost estimates of the various intercepting sewers necessary to serve the present city.

TABLE No. 17.—*Cost of east low level interceptor, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
1,000 lineal feet	18 inches diameter	8 feet	$1.50	$1,500
480 lineal feet	30 inches diameter	11 feet	5.90	2,832
610 lineal feet	36 inches diameter	12 feet	6.95	4,240
1,480 lineal feet	42 inches diameter	13 feet	8.10	11,988
1,600 lineal feet	54 inches diameter	Tunnel	8.80	14,080
1,420 lineal feet	60 inches diameter	do	14.45	20,519
2,170 lineal feet	63 inches diameter	do	15.20	32,984
4,150 lineal feet	66 inches diameter	do	16.00	66,400
3,240 lineal feet	72 inches diameter	do	17.50	56,700
Appurtenances—regulator and diversion chambers, tide gates, etc.				47,000
Collection system between interceptor and river				10,000
				268,243
15 per cent for engineering and contingencies				40,236
Total				308,479

TABLE No. 18.—*Cost of west low level interceptor, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
1,070 lineal feet	30 inches diameter	13 feet	$6.40	$6,848
660 lineal feet	36 inches diameter	15 feet	7.80	5,148
890 lineal feet	42 inches diameter	Tunnel	8.10	7,209
730 lineal feet	48 inches diameter	do	8.40	6,132
1,490 lineal feet	54 inches diameter	do	8.80	13,112
1,340 lineal feet	66 inches diameter	do	16.00	21,440
1,050 lineal feet	72 inches diameter	do	17.50	18,375
1,510 lineal feet	78 inches diameter	do	19.20	28,992
2,800 lineal feet	81 inches diameter	do	20.00	56,000
5,280 lineal feet	84 inches diameter	do	20.50	108,240
3,310 lineal feet	90 inches diameter	do	22.60	74,806
5,440 lineal feet	96 inches diameter	do	24.30	132,192
				478,494
Appurtenances—regulator and diversion chambers, tide gates, etc.				105,000
Collection system between interceptor and river				100,000
				683,494
15 per cent for engineering and contingencies				102,524
Total				786,018

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TABLE No. 19.—*Cost of River Rouge interceptor, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
2,000 lineal feet	66 inches diameter	Tunnel	$16.60	$33,000
7,500 lineal feet	72 inches diameter	do	17.50	131,250
				163,250
Lateral collectors				33,000
Appurtenances—regulator and diversion chambers, tide gates, etc				15,000
				210,250
15 per cent for engineering and contingencies				31,538
Total				241,788

TABLE No. 20.—*Cost of west high level interceptor, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
5,785 lineal feet	30 inches diameter	Tunnel	$6.40	$37,024
4,620 lineal feet	57 inches diameter	do	9.30	42,966
4,100 lineal feet	66 inches diameter	do	16.00	65,600
2,600 lineal feet	84 inches diameter	do	20.80	54,080
7,275 lineal feet	96 inches horseshoe	21 feet	27.70	201,517
11,700 lineal feet	13 by 8 feet	17.5 feet	41.10	480,870
Appurtenances—regulator and diversion chambers, etc				48,000
Lateral collectors below the interceptor				40,000
36,000 square yards repaving, at $1.50				54,000
				1,024,057
15 per cent for engineering and contingencies				153,608
Total				1,177,665

TABLE No. 21.—*Cost of additional sewers near the Fairview plant, Detroit, Mich.*

Length.	Cost per foot.	Total cost.
950 lineal feet	$17.50	$16,625
1,100 lineal feet	21.35	23,485
		40,110
15 per cent for engineering and contingencies		6,017
Total		46,127

TABLE No. 22.—*Summary of cost of interceptors and appurtenances, Detroit, Mich.*

Interceptor.	Amount.
East low level	$308,479
West low level	786,018
River Rouge	241,788
West high level	1,177,665
Additional sewers near the Fairview plant	46,127
Total	2,560,077

COST OF PUMPING STATIONS.

The cost of the two pumping stations is based on the requirements for pumping the capacity flow of the east low-level interceptor to the proposed Fairview plant, and the west low-level and River Rouge interceptors to the proposed Fort Wayne plant. Table 23 shows these requirements.

TABLE No. 23.—*Pumping requirements, Detroit, Mich.*

Interceptor.	Capacity, M. G. D.[1]	Lift in feet.
East low level	61.22	15
West low level	167.5	20
River Rouge		

[1] Million gallons per day.

In selecting equipment for the pumping stations and hence in determining upon the size of buildings, it has been assumed that use can be made of the local commercial production of electric power. No provision has been made, therefore, for the installation of a steam plant. Decision on this point rested on the grounds that the Detroit Edison Co. operates two very large central stations so well fortified that they have never yet failed to supply service.

With the above basis as a starting point, pumping equipment was selected and the size of buildings necessary for its housing determined, space being included for coarse screens and grit chambers suitable for the removal of heavy grit. The cost of buildings was estimated at 25 cents per cubic foot, including both substructure and superstructure. The cost of equipment was determined from prices of centrifugal pumps, motors, and other important items obtained from manufacturers. Table 24 shows the resulting figures, which include an allowance of 15 per cent to cover engineering and contingencies.

TABLE No. 24.—*Cost of pumping stations, Detroit, Mich., project 4, 1920.*

	Buildings.	Mechanical equipment.	Total.
Fairview station	$36,035	$37,950	$73,985
Fort Wayne station	79,352	61,410	140,762
Total	115,387	99,360	214,747

COST OF TREATMENT PLANTS.

In estimating the cost of treatment plants the following items were considered separately: Imhoff tanks, including inflowing and outflowing channels; grit chambers; sludge drying beds; disinfection plant.

Imhoff tanks, etc.—These were proportioned on the basis of a sedimentation period of two hours, when the rate of flow equals 125 per cent of the average rate of flow, and storage room for sludge of 2 cubic feet per tributary person. The size of unit selected is shown, with general dimensions, on Plate 4, and provides for the handling of 1.93 million gallons per day. For convenience in estimating, a unit cost per

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tank, including channels and appurtenances, was prepared, which, with an allowance of 15 per cent for engineering and contingencies, is $15,841. This cost figure was based on a survey of quantities, the most important of which are:

Concrete of the class of $12 per cubic yard, 642 cubic yards.
Concrete of the class of $14 per cubic yard, 95 cubic yards.
Partition walls, 290 square yards.
Excavation, 3,870 cubic yards.

Grit chambers and coarse screens.—The cost of suitable grit chambers is a relatively small percentage of the total cost of a treatment works, and no detailed study was made of this item. The estimate of its cost was made by making an allowance of 5 cents per tributary person, this figure having been arrived at from a review of published information regarding existing plants.

Sludge beds.—On account of the climatic characteristics of the district, it was deemed advisable to make estimates of sludge drying beds on the assumption that they should be covered with a glass roof to protect the sludge from rewetting by rain after it had been discharged onto the beds. The area of sludge drying beds required was based on a load of six persons per square foot of net drying bed area. Prices of wire glass were obtained for use as a basis of estimating the cost of covering, and an estimate was also made for the installation of a mechanical plant to assist in removing dried sludge from the beds. The itemized estimate of cost per square foot of sludge bed follows:

	Per square foot.
Sludge bed proper	$0.15
Roof	.47
Mechanical plant	.25
	.87
15 per cent for engineering and contingencies	.13
Total	1.00

Disinfection plants.—Inasmuch as special detention tanks are not needed for a disinfection process when detention is already provided for the purpose of sedimentation, the cost of construction for disinfection is only that required for bleach storage and mixing. This was estimated at $600 per million gallons per day. The figure was derived from a table presented by Earle B. Phelps in a paper, "Sewage purification; its theory and present-day practice," read before the Engineers' Society of Philadelphia in 1910.

Special provisions to guard against objectionable odors, etc.—It is believed that present-day practice in the design and operation of sedimentation tanks has advanced to a stage of development such that it is possible to install plants of ordinary size so that they will create little or no offense to the senses, at least when dealing with sewage under favorable conditions. It should be observed, however, that the plants proposed under this project are of rather unusual size, and are located in close proximity to residential districts. The last observation is particularly important in regard to the Fairview plant. It has been deemed wise, therefore, to include in the estimates an item to cover rather elaborate provision to prevent a possible development of nuisance conditions; to guard against explosion of gasoline vapors which are prevalent to an unusual degree in Detroit sewers, and for parking about the treatment plants. This has been done by estimating the cost of covering the tanks and constructing a high wall around them, allowances being added to cover provisions for ventilation and treatment of gases, and for landscape gardening. Whether all of this expense will prove to be necessary or not, can not well be determined with certainty in advance. Decision on this point should rest on the results of actual operation.

Table 25 gives the cost of treatment plants at Fairview and Fort Wayne for a total population of 950,000.

TABLE No. 25.—*Cost of treatment plants, Detroit, Mich., project 4, 1920.*

Treatment plants.	Population, 1920.	Average flow in M. G. D.[1]	Cost of—					
			Imhoff tanks.	Sludge beds.	Screens and grit chamber.	Disinfection.	Covering ventilation, parking.	Total.
Fairview	325,000	80.7	$444,000	$54,000	$16,300	$30,400	$130,000	$674,700
Fort Wayne	625,000	112	950,000	104,000	31,300	67,300	250,000	1,402,600
Total	950,000	162.7	1,394,000	158,000	47,600	97,600	380,000	2,077,300

[1] Million gallons per day.

COST OF DISCHARGE CONDUITS.

In estimating the cost of this item it was considered advisable to provide for the discharge of the plant effluent at different points in the cross section of the river. The construction of conduits for this purpose will be expensive on account of the general nature of the work, which will require elaborate and costly plant equipment, and will be attended by various difficulties in overcoming the natural forces at work in the river. The cost of the work has been estimated on the basis of $200 per foot of discharge conduit, with an allowance of 1,000 feet of conduit at the Fairview plant and

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an equal amount at the Fort Wayne plant. This provision, therefore, amounts to $400,000.

COST OF LAND FOR TREATMENT SITES.

It has been assumed that the Fort Wayne Military Reservation can be secured by cession from the United States Government to form a portion of the system of parks maintained by the city, and that a portion of this tract could be used for the purpose of sewage treatment.

Land would have to be purchased for the Fairview site, and as this location is in a section of high land values the high value of $40,000 per acre has been used. The plant requirements call for about 17 acres, which would on this basis cost $680,000.

COST OF OPERATION AND MAINTENANCE TO TREAT THE SEWAGE OF THE PRESENT CITY, PROJECT 4.

INTERCEPTORS.

There appears to be no reason why any large amount of money would be required for the proper operation of interceptors. The most of any such expense would be in connection with inspection and adjustment of appurtenant devices, such as regulating chambers and tide gates. It is believed that $5,000 per year is an ample amount for this purpose, and this figure has accordingly been used.

PUMPING STATIONS AND GRIT CHAMBERS ACCOMPANYING THEM.

The cost of pumping is made up of two principal parts, attendance and power, supplies, etc. In estimating the cost of attendance, allowance has been made for competent operating engineers and oilers being on duty at all times, with a further allowance for ordinary labor. The power cost has been figured from the estimated figures for volume of sewage and lift required, and a current cost of 1 cent per kilowatt. A lump-sum estimate has been included to cover the cost of supplies such as oil, waste, etc. Table 26 shows these cost figures itemized as to pumping stations and main subitems.

TABLE No. 26.—*Cost of pumping station operation, Detroit, Mich., project 4, 1920.*

Pumping station.	Average flow M. G. D.[1] per day.	Lift.	Attendance.	Power and supplies.	Removal of grit.		Total.
					Cubic yards.	Cost.	
Fairview	[2] 30	15	$12,000	$8,400	2,440	$1,220	$22,220
Fort Wayne	66	20	12,600	21,900	5,350	2,675	37,175
Total	96	.....	25,200	30,300	.....	3,895	59,395

[1] Million gallons per day.
[2] East low level interceptor only. Existing Fairview pumping station not included.

TREATMENT PLANTS.

The operating cost of the treatment works has been built up of three main items, namely, general superintendence and labor for tank operation (laboratory help included), removal of sludge and grit, and disinfection. The figures are shown in Table 27.

TABLE No. 27.—*Cost of treatment plant operation Detroit, Mich., project 4, 1920.*

Treatment plant.	Population.	Average flow M. G. D.[1]	General superintendence and labor	Removal of sludge and grit.		Disinfection at $1.63 per M.G., including labor and 5 parts per million available chlorine.	Total.
				Cubic yards.	Cost.		
Fairview	325,000	50.7	$10,700	15,800	$9,400	$30,200	$50,300
Fort Wayne	625,000	112	13,500	41,500	20,750	66,600	100,850
Total	950,000	162.7	24,200	.....	30,150	96,800	151,150

[1] Million gallons per day.

TABLE No. 28.—*Summary of cost of operation and maintenance, Detroit, Mich., project 4, 1920.*

Item.	Amount.
Interceptors	$5,000
Pumping stations	59,395
Treatment plants	151,150
Total	215,545

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COST OF CONSTRUCTION, OPERATION, AND MAINTENANCE NECESSARY TO COLLECT AND TREAT THE SEWAGE OF THE PRESENT CITY, PROJECT 5.

COST OF INTERCEPTORS.

The cost of interceptors is given in Tables 29 to 33, inclusive, and summarized in Table 34.

TABLE No. 29.—*Cost of interceptor served by the Fairview plant, Detroit, Mich., project 5, 1920.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
400 lineal feet	24 inches diameter.	12 feet	$3.10	$1,240
2,230 lineal feet	36 inches diameter.	Tunnel	7.80	18,174
400 lineal feet	42 inches diameter.	12 feet	7.80	3,120
Appurtenances				6,000
				28,534
15 per cent for engineering and contingencies				4,280
Total				32,814

TABLE No. 30.—*Cost of interceptors served by the Orleans Street plant, Detroit, Mich., project 5, 1920.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
8,650 lineal feet	42 inches diameter.	Tunnel	$3.10	$29,565
2,155 lineal feet	48 inches diameter.	Tunnel	8.40	18,102
1,600 lineal feet	54 inches diameter.	Tunnel	8.80	14,080
830 lineal feet	57 inches diameter.	Tunnel	9.30	8,277
1,730 lineal feet	60 inches diameter.	Tunnel	14.45	24,998
1,960 lineal feet	66 inches diameter.	Tunnel	16.00	31,360
2,080 lineal feet	72 inches diameter.	Tunnel	17.50	36,400
850 lineal feet	96 inches diameter.	Tunnel	24.30	13,365
Separate system between the interceptor and the river				35,000
Appurtenances, diversion chambers, etc.				65,000
				276,148
15 per cent for engineering and contingencies				41,422
Total				317,570

TABLE No. 31.—*Cost of interceptors served by the Twenty-fourth Street plant, Detroit, Mich., project 5, 1920.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
850 lineal feet	15 inches diameter.	9 feet	$1.60	$1,360
1,260 lineal feet	24 inches diameter.	11.5 feet	3.05	3,843
650 lineal feet	33 inches diameter.	14 feet	7.15	4,648
2,905 lineal feet	36 inches diameter.	Tunnel	7.80	21,579
1,510 lineal feet	48 inches diameter.	Tunnel	8.40	12,684
2,800 lineal feet	51 inches diameter.	Tunnel	8.55	23,940
1,935 lineal feet	57 inches diameter.	Tunnel	9.30	17,995
2,210 lineal feet	60 inches diameter.	Tunnel	14.45	31,934
1,740 lineal feet	66 inches diameter.	Tunnel	16.00	27,840
400 lineal feet	72 inches diameter.	Tunnel	17.50	7,000
Separate system between the interceptor and the river				75,000
Appurtenances—diversion chambers, etc.				70,000
				298,123
15 per cent for engineering and contingencies				44,718
Total				342,841

TABLE No. 32.—*Cost of interceptors served by the Fort Wayne plant, Detroit, Mich., project 5, 1920.*

Item.	Amount.
1,740 lineal feet 36-inch sewer in tunnel, at $7.80	$13,572
Appurtenances—diversion chambers, etc.	5,000
	18,572
15 per cent for engineering and contingencies	2,786
	21,358
River Rouge interceptor given under project 4, Table 22	241,788
Total	263,146

TABLE No. 33.—*Cost of interceptor and outfall served by plant at intersection of Rollins and Junction Streets, Detroit, Mich., project 5, 1920.*

Item.	Amount.
High-level interceptor given under project 4, Table 22	$1,177,000
For extension through Fort Wayne grounds and interceptions in Artillery Street	25,000
Total	1,202,000

TABLE No. 34.—*Summary of cost of interceptors, Detroit, Mich., project 5, 1920.*

Item.	Amount.
Interceptors served by plant at—	
Fairview	$322,534
Orleans Street	317,570
Twenty-fourth Street	342,841
Fort Wayne	263,146
Rollins and Junction Streets	1,202,000
Total	2,150,000

COST OF PUMPING STATIONS AND TREATMENT PLANTS.

Tables 35, 36, and 37 show the cost of pumping stations, including grit chambers, screening stations, and disinfection plants, respectively, the first two being subdivided to show the cost of buildings and machinery separately.

TABLE No. 35.—*Cost of pumping stations, Detroit, Mich., project 5, 1920.*

Pumping station.	Cost of—		Total.
	Buildings.	Machinery.	
Fairview [1]	$15,445	$20,125	$35,570
Orleans Street	65,995	46,000	111,000
Twenty-fourth Street	42,890	28,750	71,640
Fort Wayne	50,295	34,500	84,800
Rollins and Junction Streets [2]	28,450		28,450
Total	201,075	129,375	330,450

[1] New station only. Existing station to remain in service.
[2] Grit chambers only.

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Estimates of the cost of screens have been based on data supplied by the manufacturers of the Riensch-Wurl fine screen, the sizes being selected so that with one unit out of service the other units may be subjected to an overload of not more than 50 per cent.

Allowance has been made for an incinerator at each plant to burn the screenings.

TABLE No. 36.—*Cost of fine screening plants, Detroit, Mich., project 5, 1920.*

Plant.	Cost of—		Total.
	Buildings.	Machinery.	
Fairview	[1] $175,000	$138,000	$313,000
Orleans Street	155,000	184,000	339,000
Twenty-fourth Street	115,000	108,000	223,000
Fort Wayne	130,000	164,000	294,000
Rollins and Junction Streets	[1] 200,000	184,000	384,000
Total	775,000	778,000	1,553,000

[1] Buildings provided here for additional future installations.

TABLE No. 37.—*Cost of disinfection plants, Detroit, Mich., project 5, 1920.*

Plant.	Average sewage flow, M. G. D., 1920.	Cost of—		Total.
		Detention tank, at $500 per M. G. D.	Bleach storage and mixing apparatus, at $3600 per M. G. D.	
Fairview	28.3	$14,150	$16,980	$31,130
Orleans Street	41.6	20,800	24,960	45,760
Twenty-fourth Street	24.4	12,200	14,640	26,840
Fort Wayne	22.4	11,200	13,440	24,640
Rollins and Junction Streets [1]	46.0	.....	27,600	27,600
Total	162.7	58,350	97,620	155,970

[1] No detention tanks required; sewer used for this purpose.

COST OF OPERATION AND MAINTENANCE.

In making estimates of operating cost, the pumping and screening stations at each plant have been considered as a unit. Table 38 shows this cost, which has been built up from the same general items that were considered under project 4:

TABLE No. 38.—*Summary of cost of operation and maintenance, Detroit, Mich., project 5, 1920.*

Plant.	Average flow, M. G. D.	Attendance, grit chamber, pumping stations, screening stations, incinerator.	Power and supplies, including coal for burning screenings.	Removal of grit and ash from screenings.		Disinfection at $2.25 per M. G., including labor and 7 parts per million available chlorine.	Total.
				Cubic yards.	At 75 cents.		
Fairview	[1] 28.3	$22,040	$7,460	1,975	$1,480	$23,240	$54,220
Orleans Street	41.6	22,040	10,960	2,900	2,175	34,165	69,340
Twenty-fourth Street	24.4	22,040	6,430	1,710	1,285	20,040	49,795
Fort Wayne	22.4	22,840	5,900	1,560	1,170	18,395	47,505
Rollins and Junction Streets	[2] 46.0	22,040	4,250	3,210	2,405	37,780	66,475
Total	162.7	110,200	35,000	11,355	8,515	133,620	287,335
Maintenance of sewers							5,000
Total							292,335

[1] Does not include existing Fairview station.

[2] No pumping required at this plant.

DISCHARGE CONDUITS.

It has been considered that on account of the greater number of treatment plants, discharge conduits under this project would cost more than under project 4. An increase of 25 per cent has been allowed, giving a total for this project of $500,000.

LAND.

The land required is estimated to be about 7 acres, divided between the Fairview, Orleans Street, Twenty-fourth Street, and Rollins and Junction Street plants. At $40,000 per acre this amounts to $280,000.

SUMMARY OF COSTS OF PROJECTS 4 AND 5 FOR THE PRESENT CITY.

For the purpose of summarizing the costs of projects 4 and 5, the construction cost figures presented in the foregoing tables have been brought together in Tables 39 and 41, which show the first cost of all items connected with the various treatment plants under consideration, and also the annual fixed charges which this construction would entail. In Tables 40 and 42 the annual fixed charges which appeared in Tables 39 and 41, respectively, have been combined with the estimated operation and maintenance charges for the respective projects and reduced to the form of total annual charges, which is also expressed in terms of the amount of sewage and the population served.

COMPARISON OF COSTS OF SEDIMENTATION AND SCREENING TREATMENTS.

An inspection of these tables indicates that although the cost of interceptors is less for project 5 than for project 4, this saving is more than counterbalanced

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TABLE No. 39.—*First cost and annual fixed charges, Detroit, Mich., project 4, sedimentation—950,000 population in 1920.*

Plants.	Interceptors.	Other structures.	Machinery.	Land.	Total.
First cost:					
Fairview	$354,606	$910,735	$37,950	$630,000	$1,983,291
Fort Wayne	2,205,471	1,631,852	61,410	.....	3,948,733
Total	2,560,077	2,502,587	99,360	630,000	5,932,024
Annual fixed charges:					
Interest at 4½ per cent	115,203	116,666	4,471	30,600	266,940
Amortization	[1] 3,507	[2] 14,513	[3] 9,936	.....	27,961
Total	118,710	131,184	14,407	30,600	294,901

[1] 30-year life.
[2] 50-year life.
[3] 10 per cent allowance for amortization and repairs.

TABLE No. 40.—*Annual charges, Detroit, Mich., project 4, sedimentation—Designed for 162.7 M. G. D. from 950,000 population in 1920.*

Charges.	Total.	Per million gallons.	Per capita.
Fixed	$294,901	4.97	0.310
Operation and maintenance	215,545	3.63	.027
Total	510,446	8.60	.537

TABLE No. 41.—*First cost and annual fixed charges, Detroit, Mich., project 5, fine screens—950,000 population in 1920.*

Plants.	Interceptors.	Other structures.	Bleach storage and machinery.	Land.	Total.
First cost:					
Fairview	$332,814	$304,595	$175,105	$75,000	$887,514
Orleans Street	317,570	341,605	264,950	75,000	999,225
Twenty-fourth Street	342,841	270,000	151,360	75,000	839,321
Fort Wayne	263,146	291,595	211,940	.....	766,681
Rollins and Junction Streets	1,202,605	326,450	211,600	85,000	1,795,715
Total	2,159,036	1,534,425	1,004,605	250,000	4,975,486
Annual fixed charges:					
Interest at 4½ per cent	97,157	69,049	45,225	12,600	224,031
Amortization	[1] 2,958	[2] 8,593	[3] 100,560	.....	112,051
Total	100,115	77,642	145,725	12,600	336,082

[1] 30 year life.
[2] 50 year life.
[3] 10 per cent allowance for amortization and repairs.

TABLE No. 42.—*Annual charges, Detroit, Mich., project 5, fine screens—Designed for 162.7 M. G. D. from 950,000 population in 1920.*

Charges.	Total.	Per million gallons.	Per capita.
Fixed	$336,082	$5.66	$0.354
Operation and maintenance	292,335	4.92	.307
Total	628,417	10.58	.661

by the cost of expensive machinery and the increased cost of operation. The last is of course due largely to the multiplication of plants and the additional amount of disinfection necessary to treat screened sewage over that required for settled sewage. It would appear from the figures given that the sedimentation process is much to be preferred solely on the grounds of cost. It should be pointed out, however, that these figures are based on conditions that are expected to obtain in the near future, and that in order to properly weigh the merits of the two projects, conditions of ultimate development should also be considered. It is obvious that regardless of the estimated average sewage flow for 1920, the interceptors will deliver the capacity flow during times of storm, and inasmuch as the screening machinery has been selected on the basis of capacity flow, it follows that the treatment installation for project 5 will not need to be increased a very great amount in order that it may be sufficient to handle the much larger average flow which will obtain after the ultimate development of the territory served. Without going into detail, the first cost and ultimate annual fixed charges have been shown in Tables 45 and 47 for the same treatment plants that were considered in Tables 39 and 41. These include the cost of the Joy Road interceptor and the River Rouge interceptor extension, which appear in Tables 43 and 44, and have been combined as before, with the operation charges, to show total ultimate annual charges, in Tables 46 and 48.

TABLE No. 43.—*Cost of Joy Road interceptor, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total.
5,000 lineal feet	30 inches diameter	18 feet	$6.65	$33,250
7,600 lineal feet	42 inches diameter	20 feet	14.50	110,200
6,600 lineal feet	60 inches diameter	...do	21.00	138,600
7,760 lineal feet	72 inches diameter	...do	22.00	169,400
				451,450
15 per cent for engineering and contingencies				67,718
Total				519,168

TABLE No. 44.—*Cost of River Rouge interceptor extension, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total.
6,250 lineal feet	24 inches diameter	20 feet	$6.40	$40,000
2,000 lineal feet	30 inches diameter	Tunnel	6.40	12,800
2,100 lineal feet	36 inches diameter	...do	8.00	16,800
1,900 lineal feet	42 inches diameter	...do	8.10	15,390
1,800 lineal feet	48 inches diameter	...do	8.40	15,120
2,200 lineal feet	54 inches diameter	...do	8.80	19,360
2,000 lineal feet	60 inches diameter	...do	14.45	28,900
				168,370
15 per cent for engineering and contingencies				22,256
Total				170,626

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TABLE No. 45.—*First cost and fixed charges, Fairview and Fort Wayne sedimentation plants, at period of ultimate development, Detroit, Mich.*

	Interceptors.	Other structures.	Machinery.	Land.	Total.
First cost	$3,249,871	$4,118,454	$999,360	$980,000	$9,147,685
Interest at 4½ per cent	146,244	185,330	4,471	30,600	366,645
Amortization	[1] 4,452	[2] 23,063	[3] 9,936	.....	37,451
Total	150,696	208,393	14,407	30,600	404,096

[1] 80 year life.
[2] 50 year life.
[3] 10 per cent allowance for amortization and repairs.

TABLE No. 46.—*Annual charges, Detroit, Mich., Fairview, and Fort Wayne sedimentation plants at period of ultimate development—Designed for 314 M. G. D. from 1,729,800 population.*

Charge.	Total.	Per million gallons.	Per capita.
Fixed	$404,096	$3.53	$0.233
Operation and maintenance	393,095	3.43	.227
Total	797,191	6.96	.460

TABLE No. 47.—*First cost and annual fixed charges, Detroit, Mich.—Screening plants at Fairview, Orleans Street, Twenty-fourth Street, and Rollins and Junction Streets, at period of ultimate development.*

	Interceptors.	Other structures.	Machinery.	Land.	Total.
First cost	$2,848,830	$1,700,855	$1,188,995	$280,000	$6,018,680
Fixed charges:					
Interest at 4½ per cent	128,197	76,538	53,505	12,600	270,840
Amortization	[1] 3,903	[2] 9,525	[3] 118,900	.....	132,328
Total	132,100	86,063	172,405	12,600	403,168

[1] 80-year life.
[2] 50-year life.
[3] 10 per cent allowance for amortization and repairs.

TABLE No. 48.—*Annual charges, Detroit, Mich.—Screening plants at Fairview, Orleans Street, Twenty-fourth Street, and Rollins and Junction Streets, at period of ultimate development—Designed for 314 M. G. D. from 1,729,800 population.*

Charge.	Total.	Per million gallons.	Per capita.
Fixed	$403,168	$3.52	$0.234
Operation and maintenance	457,145	3.99	.264
Total	860,313	7.51	.498

It will be seen from the figures given in these tables that project 4, sedimentation and disinfection treatment, is more economical than project 5, fine screening and disinfection treatment, and it is therefore recommended as presenting the most satisfactory solution of the sewerage and sewage treatment problems of this district. Project 5 is recommended as an alternative in case future developments make it appear the more desirable.

COST OF PROJECT 4 FOR ULTIMATE DEVELOPMENT OF THE METROPOLITAN DISTRICT.

It should be noted that in the cost figures presented above the Conners Creek subproject, described on page 38, has been left entirely out of consideration. This has been done for the reason that, on account of the meagerness of fixed date available, it was impossible to make cost estimates for this project on as high a plane of accuracy as those for the rest of the district. Figures have been prepared, however, which, though approximate, merit consideration for the purpose of estimating the total cost of project 4 under conditions of ultimate development. These are presented in Tables 49 and 50, and again in Tables 51 and 52, in combination with figures already given in previous tables.

TABLE No. 49.—*Cost of Conners Creek and Forest Lawn interceptors, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
8,860 lineal feet	60-inch diameter	Tunnel..	$14.50	$128,470
14,330 lineal feet	96-inch diameter	Tunnel..	24.00	343,920
5,210 lineal feet	99-inch diameter	Tunnel..	25.00	130,250
6,260 lineal feet	108-inch diameter	Tunnel..	28.00	175,280
15,630 lineal feet	129-inch diameter	17 feet...	43.00	672,090
Minor branches				300,000
				1,750,010
15 per cent for engineering and contingencies				262,502
Total				2,012,512

TABLE No. 50.—*Cost of east high level interceptor, Detroit, Mich.*

Length.	Size.	Depth of cut.	Cost per foot.	Total cost.
4,200 lineal feet	57 inches diameter	Tunnel....	$9.30	$39,060
1,000 lineal feet	60 inches diameter	Tunnel....	14.50	14,500
2,400 lineal feet	66 inches diameter	Tunnel....	16.00	38,400
1,400 lineal feet	69 inches diameter	Tunnel....	16.70	23,380
8,300 lineal feet	72 inches diameter	22.5 feet...	22.50	186,750
Appurtenances, regulators, and diversion chambers				30,000
Collection system below the interceptor				30,000
				362,090
15 per cent for engineering and contingencies				54,314
Total				416,404

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TABLE No. 51.—*Summary of cost of interceptors and appurtenances, Detroit, Mich., project 4, at period of ultimate development.*

Interceptor.	Reference.	Amount.
East low level	Table 22...	$308,479
West low level	...do.....	736,018
River Rouge	...do.....	241,788
West high level	...do.....	1,177,665
Additional sewers near the Fairview plant	...do.....	46,127
Joy Road	Table 43...	519,108
River Rouge extension	Table 44...	170,626
Conners Creek and Forest Lawn	Table 49...	2,012,512
East high level	Table 50...	416,404
Total	.....	5,678,787

TABLE No. 52.—*Cost of treatment plants, Detroit, Mich., project 4, at period of ultimate development.*

Plant.	Estimated population.	Amount.
Fairview	651,114	[1] $1,308,444
Fort Wayne	1,078,700	[1] 2,294,623
Connors Creek	901,536	1,913,749
Total	2,631,350	5,516,816

[1] This amount appears under "other structures" in Table No. 45, in combination with the cost of discharge conduits and pumping station buildings, as given in Table 24.

TABLE No. 53.—*First cost and annual fixed charges, Detroit, Mich., project 4, at period of ultimate development.*

	Interceptors.	Other structures.	Machinery.	Land.	Total.
First cost	$5,678,787	$4,082,207	$124,360	$1,020,000	$12,905,353
Fixed charges:					
Interest at 4½ per cent	255,545	273,699	5,596	45,900	580,740
Amortization	[2] 7,780	[3] 34,060	[3] 12,436	.....	54,276
Total	263,325	307,759	18,032	45,900	635,016

[1] 80-year life.
[2] 50-year life.
[3] 10 per cent allowance for amortization and repairs.

TABLE No. 54.—*Annual charges, Detroit, Mich., project 4, at period of ultimate development—Designed for 491 M. G. D. from 2,631,350 population.*

Charge.	Total.	Per million gallons.	Per capita.
Fixed	$635,016	$3.54	$0.241
Operation and maintenance	525,545	2.93	.200
Total	1,160,561	6.47	.441

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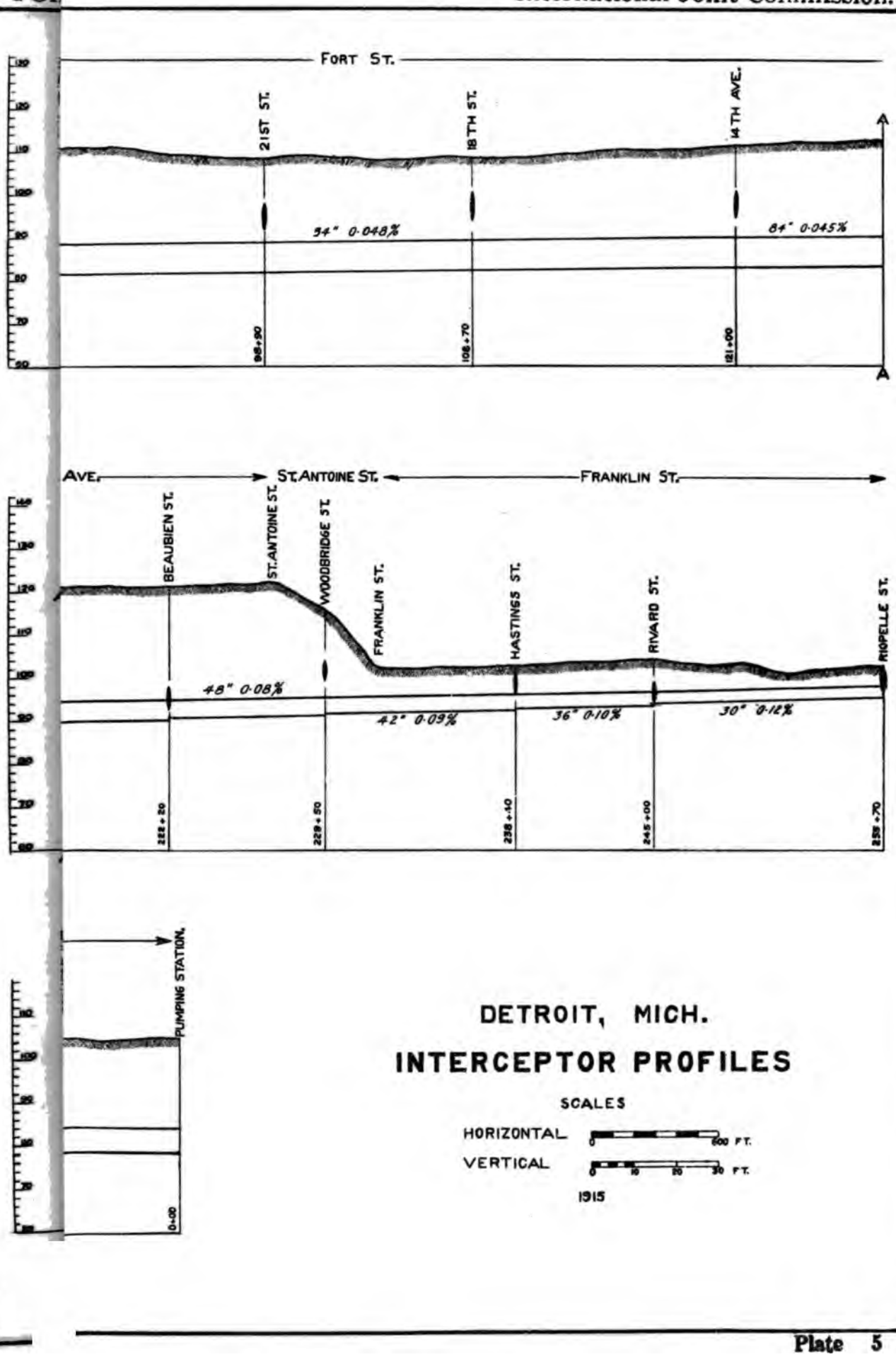

DETROIT, MICH.

INTERCEPTOR PROFILES

SCALES

HORIZONTAL 0 600 FT.

VERTICAL 0 10 20 30 FT.

1915

Plate 5

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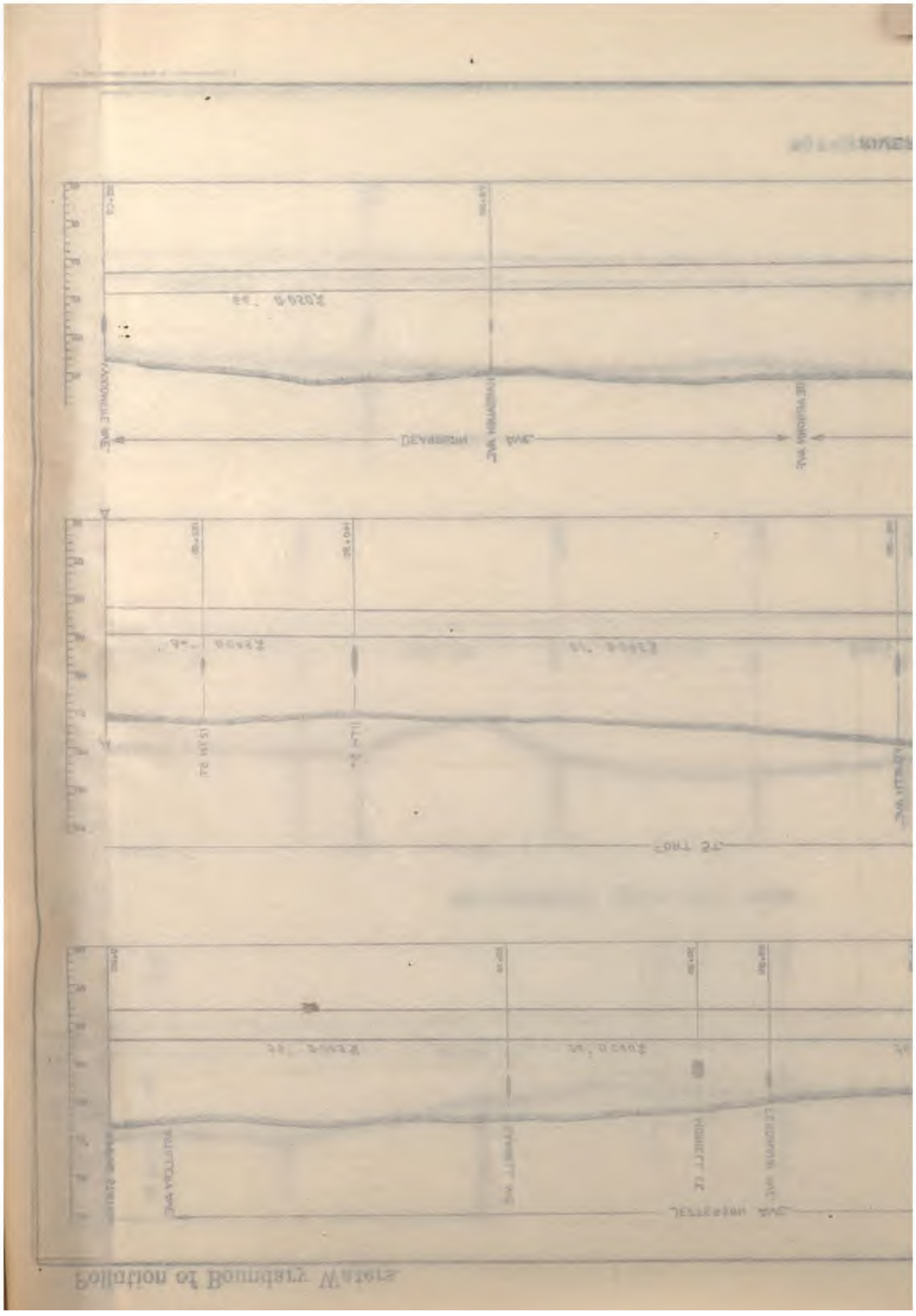

TABLE No. 58.—*Cost for Windsor district, Ontario—110,000 population.*

Item.	Unit price per foot.	Cost.	Total cost.
Sewer and appurtenances from Table 56			$245,086
High-level interceptor:			
2,600 feet of 24-inch sewer	$7.00	$18,200	
4,000 feet of 27-inch sewer	7.90	31,600	
6,230 feet of 33, 36 and 39 inch sewer	8.20	51,086	
2,900 feet of 42-inch sewer	9.30	26,970	
2,070 feet of 45-inch sewer	9.50	19,665	
4,270 feet of 48-inch sewer	10.00	42,700	
4,800 feet of 54-inch sewer	11.60	55,680	
Appurtenances—diversion chamber and regulators		20,000	
Additional collection system for Ford City		37,500	
			303,401
Pumping stations:			
Buildings		11,900	
Machinery		15,800	
			27,700
Treatment plant, including Imhoff tanks, sludge beds, grit chambers, and disinfection apparatus	[1] 2.20	242,000	
Treatment plant at foot of Park Street		2,000	
			244,000
Land			9,000
Total			829,187

[1] Per capita.

Table 59 shows the annual charge which results from the above estimate, and the cost of operation, which is estimated at $25,000 per year for labor and materials.

TABLE No. 59.—*First cost and annual charges, Windsor district, Ontario—110,000 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	[1] $754,387	$15,800	$9,000	$779,187.00
Interest at 4½ per cent	33,947	711	405	35,063.00
Amortization	[2] 4,225	[3] 1,580		5,805.00
Fixed charges	38,172	2,291	405	40,868.00
Operation charge				25,000.00
Total annual charge				65,868.00
Annual charge per capita				.60

[1] Exclusive of collection system for Ford City.
[2] 50-year life.
[3] 10 per cent allowance for amortization and repairs.

It should be noted that the items for collection system in Ford City have been disregarded in the preparation of Tables 57 and 59. This has been done because this cost is not considered as incidental to the installation of the treatment plant.

Acknowledgment.—The kind cooperation of Mr. M. E. Brian, city engineer of Windsor; Mr. Charles Montreuil, mayor of Ford City; Mr. Owen McKay, engineer for Ford City, Walkerville, and Sandwich; and Mr. J. J. Newman, civil engineer, Windsor, Ontario, was of great assistance in the studies undertaken for the Windsor district.

PORT HURON, MICH.

Port Huron, Mich., is situated on the St. Clair River at its source, the northern portion being, in fact, above the source of the river, on the shore of Lake Huron. Black River, a tributary of the St. Clair River, divides the city into two parts of approximately equal area. There is so much territory included within the corporate limits of the city which is at present absolutely undeveloped that there is little doubt as to the ability of the city to accommodate future growth for a great number of years without annexing outlying territory. The city is a distributing point for a growing agricultural section and is entered by the Pere Marquette and Grand Trunk Railroads, the latter connecting with the East by way of Canada through a tunnel under the St Clair River. There is also an interurban electric line which connects with Detroit and intervening towns and a ferry line which makes frequent trips across the river to Sarnia. Railroad activities have been important in the past, and, though reduced in recent years, promise to revive somewhat. There is a fair amount of manufacturing—flour mills, foundries, agricultural implement, automobile, and rug factories, and breweries, representing the main lines of endeavor in this direction. The topography is characteristic of the district, providing easy slopes, though some parts of the city are higher above the water than many communities on the Michigan side.

The sewers are all of the combined type, with outlets located at levels approximately corresponding to normal river stages.

There are 14 outlets, 6 of which discharge into the Black River. The other 8 discharge into the St. Clair at points distributed over a distance of more than 4 miles.

The population was 13,543 in 1890, 19,158 in 1900, and 18,863 in 1910, the decrease being due in part, if not entirely, to the removal of the car shops of the Grand Trunk Railroad. The present population is estimated to be between 18,000 and 20,000, and as preparations are under way to move the car shops back it can reasonably be expected that there will be a moderate increase in future years.

It has been assumed in this investigation that present treatment plant construction should be based on a population of 25,000, and that the interceptors should provide for a population of 40,000.

The water consumption is very high, about 365 gallons per capita per day, and after making proper allowance for water used by railroads and manufacturing there still remains about 250 gallons per capita per day for domestice use and waste. Investigations made by the city engineer indicate that the waste is excessive, and he concurs in the belief that it may reasonably be expected to be reduced to a

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large extent. In fact, meter records have been made which indicate an actual domestic consumption of less than 50 gallons per capita per day. A daily per capita consumption of 125 gallons has therefore been taken as a reasonable average on which to base the studies of this investigation.

In fixing the size of interceptors it has been assumed that the tributary areas will be built up to an average density of 20 persons per acre; that the portion of the city between Black River and Lincoln Street will return to the sewers 120 gallons per capita per day, and that the remainder of the city will return 80 gallons per capita per day. The higher figure is used for the central portion of the city to cover the allowance for commercial and manufacturing consumption, it being difficult in this case to delimit areas sufficiently typical for the purpose of covering the additional consumption from these sources. An allowance of from 500 to 1,500 gallons per acre has been made for ground water, according to local subsoil conditions. A search for sites suitable for treatment works disclosed the fact that there are none along the St. Clair River which would not require excessive pumping. There are two, however, one on each side of the Black River a short distance below the Pere Marquette Railroad, which offer attractive possibilities, and interceptor studies have centered around these. Investigation finally indicated the site on the south side of Black River near Short Street to be the more favorable of the two. The interceptors to this site are shorter and somewhat shallower at the lower end, and less pumping is required. Furthermore, the outfall from the treatment plant to the St. Clare River can be made shorter and can be constructed without interference with existing sewers, such as would result if the plant were located on the north side. Plate 12 shows the interceptor layout which has been adopted. It consists of two main systems, one south and one north of the Black River. The main part of the south system, shown in profile on plate 13, begins at Tenth and Beard Streets and follows Beard Street to Military Street, thence to the railroad tracks, which it follows to Griswold Street. It then follows Griswold Street to Fourth Street, to the automatic pumping station at Fourth and Court Streets, where it has been planned to lift the sewage. The interceptor then continues along Fourth Street to Water Street, to the treatment plant. There is also a short line which follows Water Street from Fourteenth Street to the treatment plant.

The north side system is composed of three lines, which center at the automatic pumping station at Park and River Streets. The north branch, shown in profile on plate 14, follows Lincoln and Willow Streets from the Waterworks Park. The west branch, shown in profile on plate 13, follows River Street through its entire length from Tenth Street. The east branch, shown in profile on plate 14, is formed by the junction of two subsidiary branches in Merchant Street, and follows Sarnia Street to Michigan Street, thence to Quay Street, to Erie Street, to River Street, to the pumping station, where the sewage from the north and east branches will be pumped to the level of the west branch and discharged by a siphon under the river into the south side interceptor in Water Street at its intersection with Skinner Street. By having the treatment plan located on the south side of Black River, with the above-described arrangement of interceptors, nearly 70 per cent of the ultimate sewage will need to be pumped only a few feet.

As previously mentioned, there are large undeveloped areas within the city limits, and some of these will probably remain in an undeveloped state for many years. The interceptors have been planned to provide for what seems to be a reasonable development. It has been considered that all existing combined sewers will remain such, except that in Beard Street west of Sixteenth Street.

The area west of Sixteenth Street is undeveloped at present, and this should be sewered under a separate system plan. A future trunk collector has been provided at Twentieth Street to convey the sanitary sewage of this district to the existing 33 by 50 inch sewer in Howard and Sixteenth Streets.

The interceptor in Water Street from Skinner Street to the treatment plant has been figured large enough to take the sewage from this area.

The undeveloped area in the northern portion of the city should also be sewered on a separate plan, and the storm water discharged into Lake Huron, the St. Clair River, or Black River. The sanitary sewage should be collected at some convenient central point and pumped into the existing combined system. Provision has been made in the capacity of the interceptors in River and Water Streets for a reasonable growth in this district. The interceptor in Water Street has been designed of sufficient capacity to take the sewage from both the northern section and the section west of Sixteenth Street which was referred to above.

The plan described above takes no cognizance of the development at the extreme southern end of the city known as South Park. This section was eliminated from this plant in order to obviate the necessity for the very long interceptor line which would be required were it included. There are a relatively small number of people in South Park at the present time, and probably will not be many more for some years to come. It has been considered best that this community be served by a small local treatment plant which might in later years be enlarged to accommodate the undeveloped area south of Beard Street in case this territory should be built up for residential purposes.

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There has been provided, and shown on Plate 12, an outfall sewer from the main treatment works which crosses under the Black River and follows Stanton Street to the St. Clair River. This outfall has been included because there is a reasonable doubt as to the ability of the Black River to absorb the treatment plant effluent without attendant nuisance. Practically, in developing the project and putting it on a working basis, there would be no objection to omitting the outfall sewer at the start, in order that the urgency of its need might be determined. No construction should be undertaken, however, that would prevent the possibility of its ultimate inclusion in the project.

Two cost estimates are presented herewith, one based on a population of 25,000, which may be expected within the next few years, and the other designed to meet the needs of the more distant future, with a population of 40,000. The estimates for interceptors are the same in each case, being based upon the larger future population.

TABLE No. 60.—*Cost for Port Huron, Mich.—25,000 population.*

Item.	Unit price per foot.	Cost.	Total cost.
South Side interceptor:			
9,850 feet of 15, 18, 20, and 22 inch sewer	$4.90	$48,265	
2,900 feet of 45-inch sewer	10.00	29,000	
Willow Street interceptor:			
3,210 feet of 8 and 10 inch sewer	5.55	17,816	
North Side and Tenth Street interceptor:			
6,240 feet of 10, 12, and 24 inch sewer	5.85	36,504	
375 feet of 30-inch sewer	7.00	2,625	
Siphon under Black River		5,000	
Outfall to St. Clair River:			
4,075 feet of 48-inch sewer	13.00	52,975	
Siphon under Black River		5,000	
Appurtenances—diversion chambers and tide gates		7,000	
			$304,185
Pumping station:			
Buildings—			
Fourth Street	$2,850		
River Street	3,800		
Water Street	4,750		
		11,400	
Machinery—			
Fourth Street	2,800		
River Street	2,500		
Water Street	6,000		
		11,300	
			22,700
Treatment plant, including Imhoff tanks, sludge beds, grit chambers, and disinfecting apparatus	[1] 2.35		58,750
South Park treatment plant			2,500
Land			3,000
Total			291,135

[1] Per capita.

The cost of operation has been based on the assumption that the pumping stations will be, so far as possible, operated automatically, and therefore require only a minimum of attention. On this basis the combined operation cost of the treatment plant and pumping stations has been estimated at $9,000 per year for labor and materials.

Table 61 shows the annual charge which results from the estimates given above.

TABLE No. 61.—*First cost and annual charges for Port Huron, Mich.—25,000 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	$276,835	$11,300	$8,000	$291,135
Interest at 4½ per cent	12,458	508	135	13,101
Amortization	[1] 1,550	[2] 1,130		2,680
Fixed charges	14,008	1,638	135	15,781
Operation charge				9,000
Total annual charge				24,781
Annual charge per capita				.99

[1] 50-year life. [2] 10 per cent allowance for amortization and repairs.

TABLE No. 62.—*Cost for Port Huron, Mich.—40,000 population.*

Item.	Unit price.	Cost.	Total cost.
Interceptor and outfall as in Table 60		$204,185	
Interceptor in Twentieth Street:			
7,173 feet of 15, 20, and 24 inch sewer	[1] $4.00	28,692	
			$232,877
Pumping station:			
Buildings		11,400	
Machinery		12,900	
			24,300
Treatment plant, including Imhoff tanks, sludge beds, grit chambers, and disinfection apparatus	[2] 2.35		94,000
South Park treatment plant			2,500
Land			3,000
Total			356,677
Annual cost of operation			11,000

[1] Per foot. [2] Per capita.

TABLE No. 63.—*First cost and annual charges for Port Huron, Mich.—40,000 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	$340,777	$12,900	$3,000	$356,677
Interest at 4½ per cent	15,335	581	135	16,051
Amortization	[1] 1,908	[2] 1,290		3,198
Fixed charges	17,243	1,871	135	19,249
Operation charge				11,000
Total annual charge				30,249
Annual charge per capita				.76

[1] 50-year life. [2] 10 per cent allowance for amortization and repairs.

Acknowledgment.—The cooperation of Mr. Earle P. Whitmore, city engineer, in supplying maps, field

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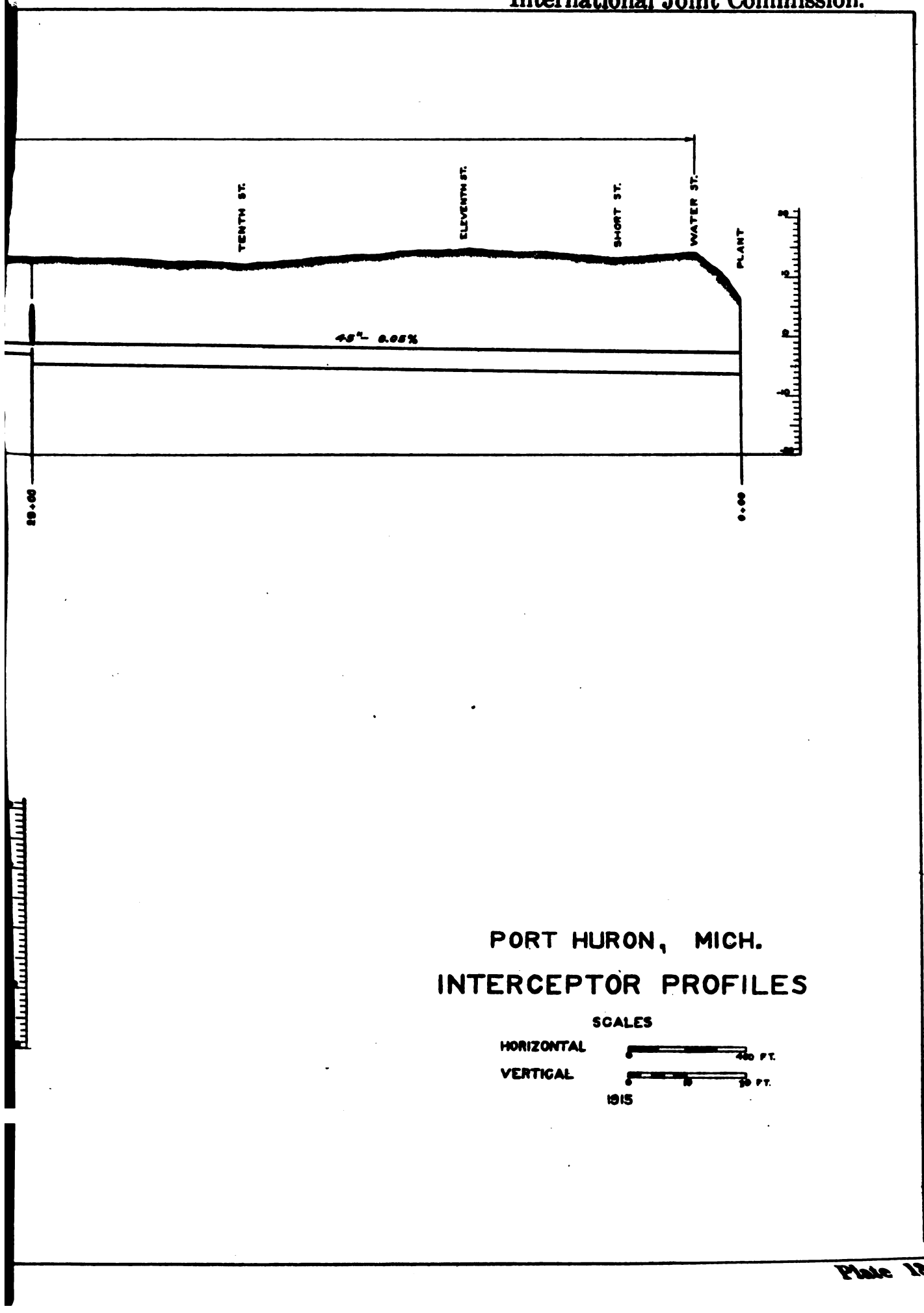

PORT HURON, MICH.

INTERCEPTOR PROFILES

SCALES

HORIZONTAL 0 400 FT.

VERTICAL 0 10 20 FT.

1915

Plate 18

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higher than the river. Railroad facilities are provided by the Michigan Central and an interurban electric line which connects with Detroit, Port Huron, and other river cities.

TABLE No. 65.—*First cost and annual charges for Sarnia, Ontario—16,000 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	$93,450	$3,800	$3,000	$100,250.00
Interest at 4½ per cent	4,205	171	135	4,511.00
Amortization	[1] 523	[2] 380	.....	903.00
Fixed charges	4,728	551	135	5,414.00
Operation charge	.....	.....	.....	6,000.00
Total annual charge	.....	.....	.....	11,414.00
Annual charge per capita	.....	.....	.....	.71

[1] 50-year life.
[2] 10 per cent allowance for amortization and repairs.

There are 12 sewer outlets which discharge at about the normal river stage, 6 into the Pine River and 6 into the St. Clair. Two of the latter discharge above the waterworks intake.

The population has remained nearly stationary for the last 25 years, ranging from 2,350 in 1890 to about 2,600 at the present time. There seems to be no reason to expect an increased rate of growth in the future, and it has been considered ample for the purpose of this investigation to provide treatment-plant capacity for 3,000 persons, and interceptor capacity for 3,500 persons.

The waterworks records indicate an average consumption of about 200 gallons per capita per day. The records appear to be fairly good, and if accurate they obviously show that there is excessive waste, probably due in large measure to leaky mains and to lawn sprinkling in the summer time.

In calculating the size of interceptors it has been assumed that each person would contribute 80 gallons per day, and an additional allowance has been made for ground water at the rate of 1,000 gallons per acre per day. It has been considered that the future city will cover 270 acres, with population density of 13 per acre, which is only slightly less than the present density of a typical section in the central part of the city.

Three possible sites for a treatment plant were studied. One of them, located down the river from the city, was abandoned without detailed study because it obviously required an unduly expensive interceptor line. Another, located on the west side of the Pine River, was studied in detail, but found to require a more expensive system of interceptors than the site east of the Pine River, which is indicated on plate 16.

The interceptors which have been laid out to convey the sewage to a pumping station at this site are three in number, and are also shown on plate 16. The two most important of these, shown in profile on plate 17, are on the north side, and the third, a very small one, is on the south side of Pine River. The largest and longest line begins at Vine Street and follows Riverside Avenue to Clinton Street, to Fourth Street, where it is joined by a shorter line which begins at Juliet Street and follows Sixth Street to Cedar Street, to Fifth Street, to Clinton Street, to Fourth Street. From this point the course is in Fourth Street to the river, where an underwater crossing is provided to carry the sewage under the river to the pumping station. The third line on the south side of the river is to divert the sewage in the existing Riverside Avenue sewer directly to the pumping station. The treatment plant, though located on the Pine River, which is quite sluggish at certain seasons of the year, is not far from the St. Clair River, and it has been considered sufficient to provide for the discharge of the treatment plant effluent directly into the Pine River. The estimated cost of this project is presented herewith as follows, and includes the cost of a separate sludge digestion tank, not shown on the plate:

TABLE No. 66.—*Cost for St. Clair, Mich.—3,000 population.*

Item.	Unit price.	Cost.	Total cost.
4,660 feet of 8, 10, and 12 inch sewer	[1] $2.55	$11,883	
Underwater crossing and appurtenances	.....	4,500	
			$16,383
Pumping station:			
Building and pump well	.....	2,550	
Machinery and piping	.....	2,130	
			4,680
Treatment plant, including Imhoff Tank sludge bed, grit chamber, and disinfection apparatus	[2] 2.25	.....	6,750
Land	.....	.....	250
Total	.....	.....	28,063

[1] Per foot. [2] Per capita.

TABLE No. 67.—*First cost and annual charges for St. Clair, Mich.—3,000 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	$25,683	$2,130	$250	$28,063
Interest at 4½ per cent	1,156	96	11	1,263
Amortization	[1] 144	[2] 213	.....	357
Fixed charges	1,300	309	11	1,620
Annual operation charge	.....	.....	.....	1,200
Total annual charge	.....	.....	.....	2,820
Annual charge per capita	.....	.....	.....	.94

[1] 50 year life.
[2] 10 per cent allowance for amortization and repairs.

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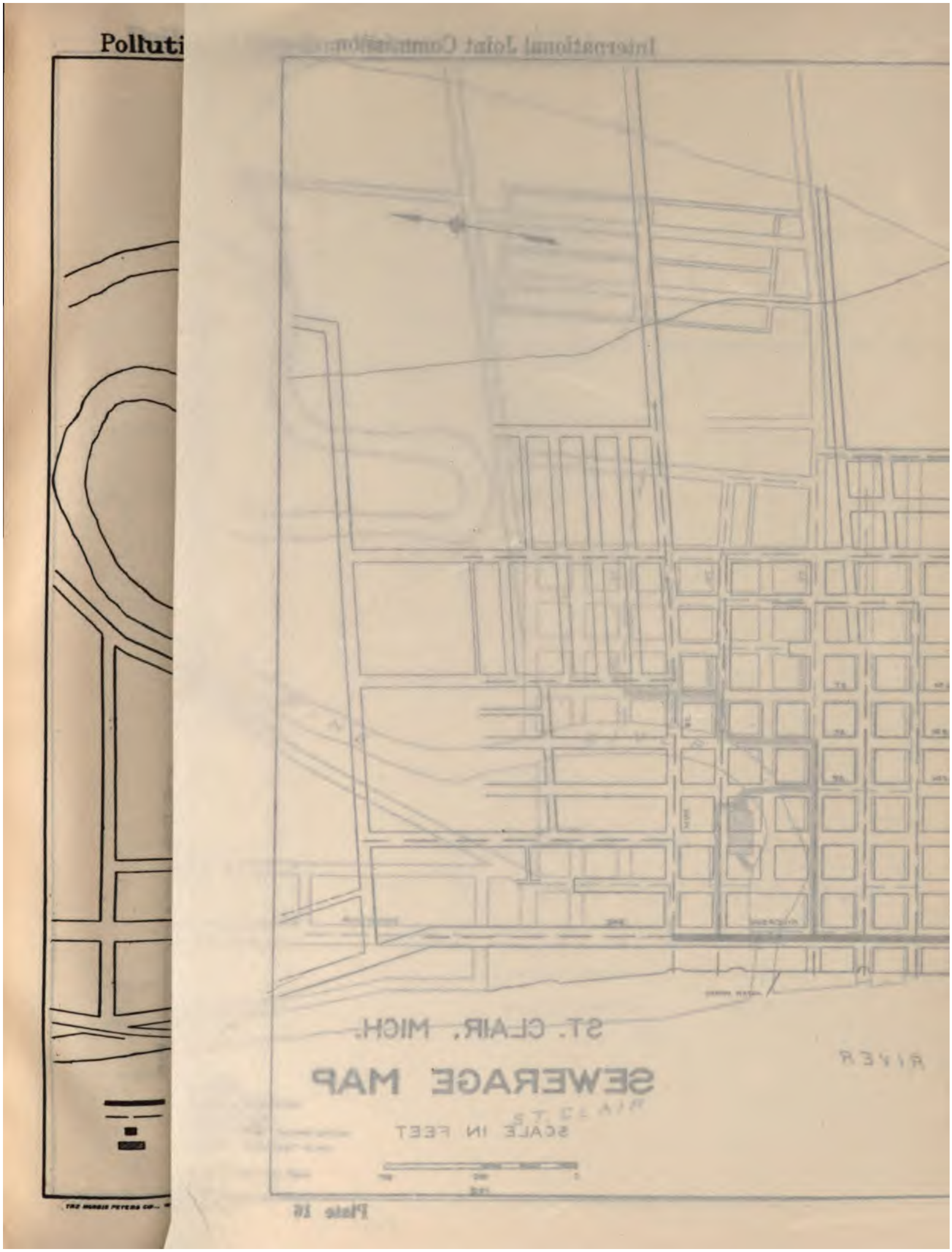

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on such meager data. The cost of a tank for separate sludge digestion, not shown on the plates, is included.

Unfortunately, there is no electric current available in Marine City except during the night when the municipal lighting plant is in service, and this state of affairs seriously affects any plans for the installation of automatic pumping stations. It has been considered that a small generating set might be erected in the waterworks pumping station and operated by the engineers of that station so that current might be available at all times. On this basis the operation cost for labor and materials has been estimated at $1,700 per year.

Table 69 shows the annual charge which results from the estimates given above.

TABLE No. 69.—*First cost and annual charges for Marine City, Mich.—4,000 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	$57,440	$5,000	$500	$62,940.00
Interest at 4½ per cent	2,585	225	23	2,833.00
Amortization	[1] 322	[2] 500		1,822.00
Fixed charges	2,907	725	23	3,655.00
Operation charge				1,700.00
Total annual charge				5,355.00
Annual charge per capita				1.34

[1] 50-year life. [2] 10 per cent allowance for amortization and repairs.

Acknowledgment.—The data obtained at Marine City was made available by the courtesy of the mayor, Mr. G. W. Becker.

ALGONAC, MICH.

The city of Algonac, Mich., is located on the St. Clair River just along the main portion of the delta which forms the St. Clair Flats. It can hardly be classed as a sewered city, there being at present only three sewer outlets serving about 80 houses.

The normal year round population of Algonac has remained practically stationary at 1,200 for the past 15 years, but is augmented in the summer to between 2,500 and 3,000 persons. There are three manufacturing plants producing motor boats, sashes and doors, and cement blocks. Owing to the proximity of the city to the rapidly expanding Detroit district, it seems probable that there will be a gradual increase of normal population and a more rapid growth of the additional summer population. The interceptor plan has been designed for a population of 2,400, which it is believed will provide for reasonable growth for many years, and also for the small amount of additional sewage contributed by quite a large summer colony. The treatment-plant provision is for 1,700 persons.

The water records are inadequate, but seem to indicate an average daily per capita consumption of about 100 gallons.

The present city contains 107 acres, and the population density, based on the normal population, is 11 persons per acre. This is quite low, but is increased materially in the summer time.

The interceptor has been designed on the basis of 15 persons per acre, and an assumed future acreage of 160, with a sewage contribution of 80 gallons per capita per day, and a further allowance of 1,000 gallons per acre for ground water. As shown on plate 19, and in profile on plate 20, this interceptor begins at Mill Street and follows Water Street to Liberty Street, thence to Michigan Street, to a pumping station at the proposed treatment plant south of the city. A short outfall will be required to carry the effluent to the St. Clair River.

The estimated cost of the project is presented herewith as follows, and includes the cost of a separate sludge digestion tank not shown on the plates.

TABLE No. 70.—*Cost for Algonac, Mich.—1,700 population.*

Item.	Unit price.	Cost.	Total cost.
4,130 feet of 8 and 10 inch sewer	[1] $1.15	$4,750	
700 feet of outfall to the river	[1] 2.00	1,400	$6,15
Pumping station:			
Building and pump well		2,000	
Machinery and piping		2,000	4,00
Treatment plant, including Imhoff tank, sludge bed, and disinfection apparatus	[2] 2.50		4,25
Land			25
Total			14,65

[1] Per foot. [2] Per capita.

Table 71 shows the annual charge which results from the estimates given above.

TABLE No. 71.—*First cost and annual charges for Algonac, Mich.—1,700 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	$12,400	$2,000	$250	$14,650.00
Interest at 4½ per cent	558	90	11	659.00
Amortization	[1] 69	[2] 200		269.00
Fixed charges	627	290	11	928.00
Operation charge				1,400.00
Total annual charge				2,328.00
Annual charge per capita				1.37

[1] 50-year life. [2] 10 per cent allowance for amortization and repairs.

The cost of the pumping station is increased by the fact that there is no electric current available in Algonac except at night, when the municipal power plant is in operation. Provision has therefore been made for a gasoline engine to supply power in the daytime, with the intention that the station be oper-

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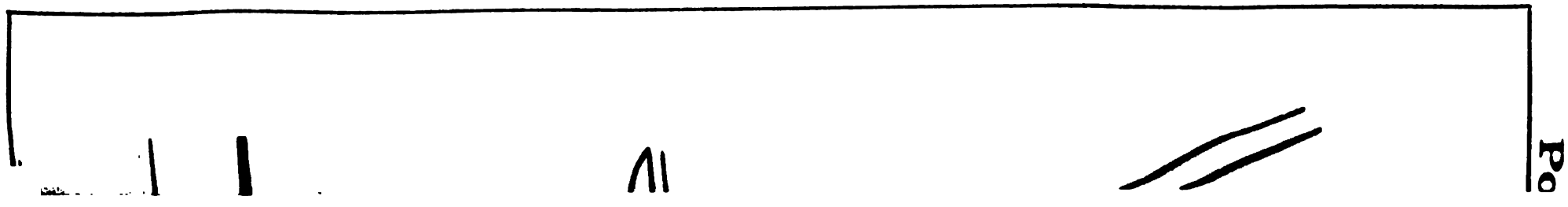

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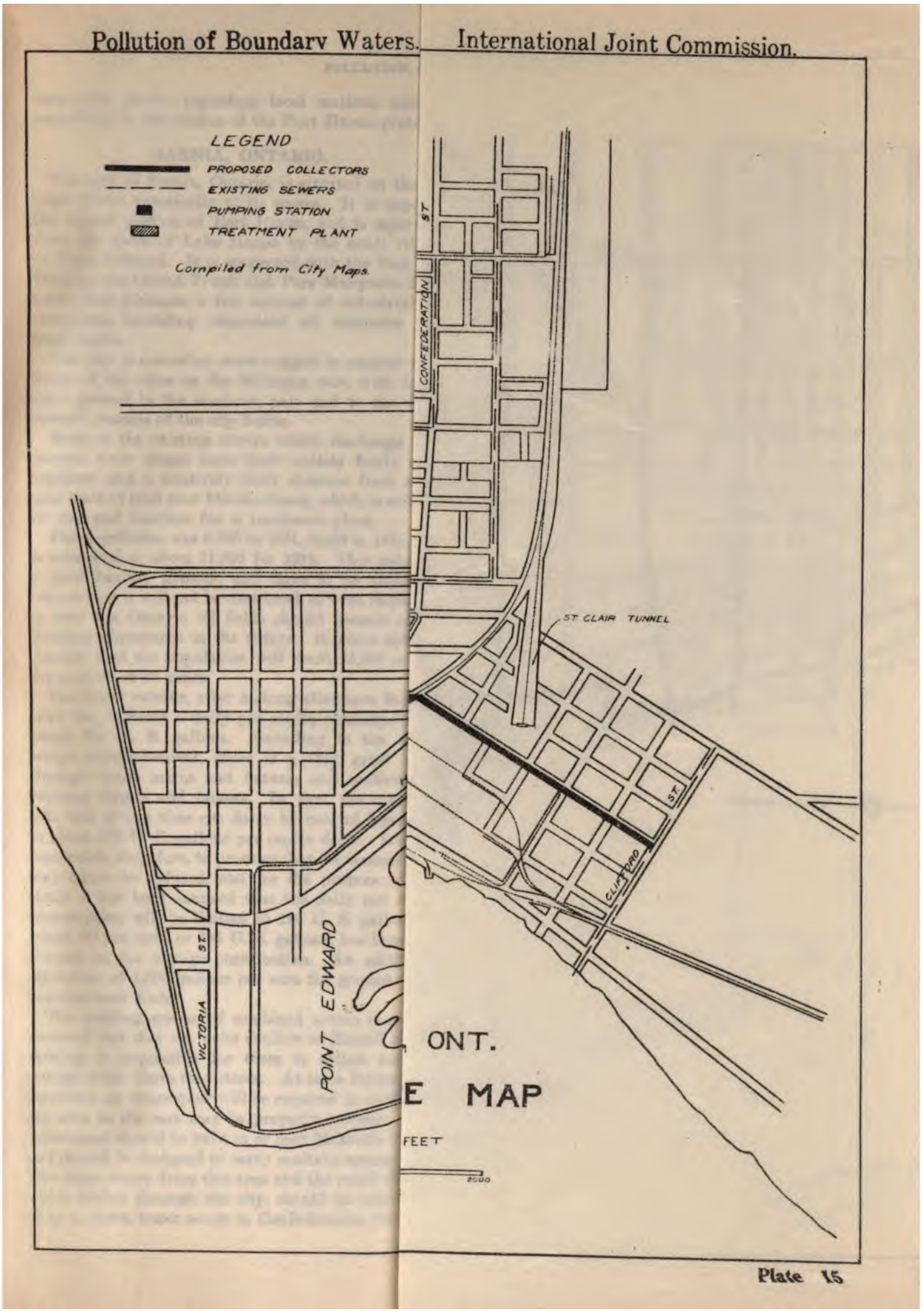

Plate 15

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TABLE No. 78.—*Cost for Ford City, Mich.—5,000 population.*

Item.	Unit price.	Cost.	Total cost.
4,190 feet of 12 and 15 inch sewer	[1] $3.35	$14,037	
Outfall and appurtenances		1,000	$15,037
Pumping station:			
Buildings		2,000	
Machinery		2,000	4,000
Treatment plant, including Imhoff tanks, sludge beds, grit chambers, and disinfection apparatus	[2] 2.35		11,750
Land			1,500
Total			32,287

[1] Per foot. [2] Per capita.

TABLE No. 79.—*First cost and annual charges for Ford City, Mich.—5,000 population.*

	Interceptors and other structures.	Machinery.	Land.	Total.
First cost	$28,787	$2,000	$1,500	$32,287.00
Interest at 4½ per cent	1,295	90	68	1,453.00
Amortization	[1] 161	[2] 200		361.00
Fixed charges	1,456	290	68	1,814.00
Operation charge				1,600.00
Total annual charge				3,414.00
Annual charge per capita				.68

[1] 50-year life. [2] 10 per cent allowance for amortization and repairs.

Acknowledgment.—Maps and sewerage data for Ford City were obtained through the kindness of Mr. Mason L. Brown, civil engineer, Detroit, Mich.

WYANDOTTE, MICH.

The city of Wyandotte, Mich., is situated on the Detroit River just below and immediately adjacent to the village of Ford City. Like most of the Detroit River towns on the Michigan side, it is flat and low. It is a thriving city, the principal manufacturing industry being represented by the Michigan Alkali Co.'s plant No. 1, which employs a large number of men. There is connection with Detroit by means of the Michigan Central and Lake Shore & Michigan Southern Railroads, and two electric lines.

The population was 3,000 in 1890, 5,200 in 1900, and 8,300 in 1910, and is estimated to be about 10,000 at present. From this record of growth and the probability of an overflow population from Detroit, it would seem wise to provide interceptor capacity for a future population of about 30,000, and this number of people has been assumed as distributed over the 1,120 acres contained within the city limits, as follows:

On the area west of the railroad right of way, which is only sparsely settled at present and not sewered, 2 persons to the acre.

On the area west of the railroads and north o Maple Street, 30 persons per acre.

The available water records cover only the perio since February, 1914, but are sufficiently detailed an seem sufficiently reliable to indicate with a fair degre of certainty that the amount consumed per capit daily is about 130 gallons. It has been considere that this may be increased to 150 gallons with th growth of the city, and that the sewage contribution including that from domestic, commercial, and manufacturing sources will amount to 120 gallons per capita per day. This quantity, with a further allowance for ground water of 1,000 gallons per acre per day, has been used.

The existing sewerage system has four points of outlet, the most important being in Chestnut Street, where two 48-inch sewers discharge about three-fourths of the sewage of the present city. There is no river front property which seems to be available for a treatment site in the lower part of the city, so that any attempt to establish a treatment plant in that section would involve a long outfall line. In view of this and the fact that most of the sewage is discharged in the upper or northern section of the city it has been considered advisable from the standpoint of economy to plan on bringing the small amount of sewage from the lower portion of the city up to the Chestnut Street outlets instead of following the usual procedure of carrying all the drainage downstream. Fortunately there is ample land available for a treatment plant, and, although it is near a good residence district, no objectionable conditions should arise from a properly designed and operated plant so located.

The interceptor as shown on plate 27 and in profile on plate 28 begins at Vassar Street and follows Biddle Avenue to Orange Street, thence to Vanalstyne Boulevard, to a pumping station at the treatment-plant site. The sewage in the sewers in Chestnut Street might be allowed to flow through the plant by gravity, but these sewers are now at such a level that ordinary velocities in them are very low, and as the additional head loss incident to the treatment plant will make them lower still, and also cause settling velocities in influent channels to settling tanks, it would be better from an operating standpoint to pump this sewage a few feet also. Estimates have been made on this basis. It will eventually be necessary to pump the sewage from the now partially developed section west of the railroad. This should be collected by a separate system of sewers and lifted into the Chestnut Street sewer by an automatic pumping station in Eighth Street.

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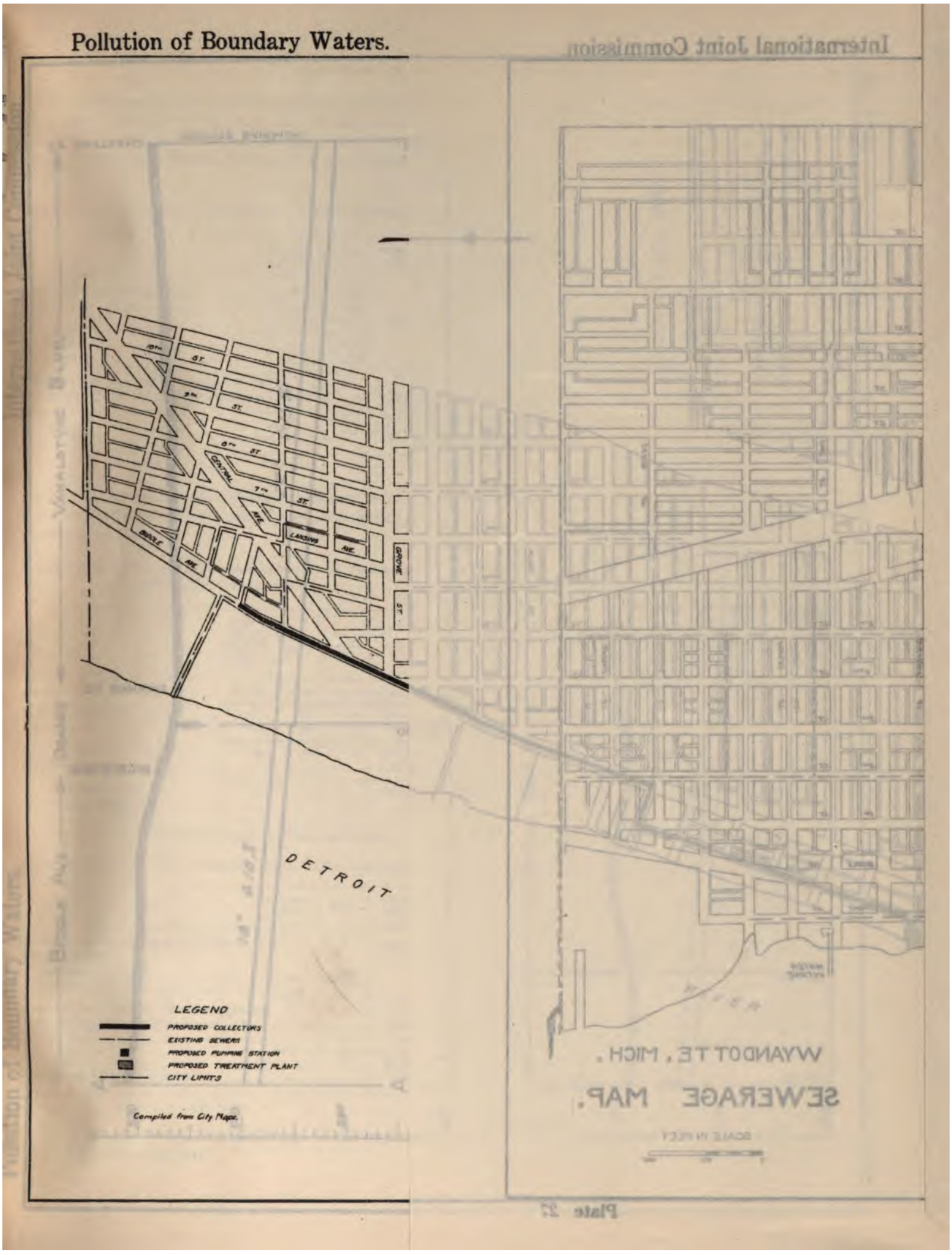

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On account of the distance from Detroit, about 11 miles, it does not seem likely that it will be affected by overflow from there for a long time.

The water-pumping records, after making allowance for use by railroads, indicate a daily per capita consumption of 133 gallons. As this is obviously too high for this community, there must be a large waste by leakage, lawn sprinkling, etc. For the purpose of sewer design it has been assumed that 80 gallons per day will be contributed by each person and that there will be an additional flow of 500 gallons per acre from infiltration of ground water.

The sewer layout is shown on plate 29, with a treatment plant discharging into the small creek south of the city, and the estimated cost of the project is presented herewith, as follows:

TABLE No. 84.—*Cost for Trenton, Mich.—1,200 population.*

Item.	Unit price.	Cost.
20,400 feet of 8-inch, 10-inch, and 12-inch sewer	[1] $0.90	$18,360
Treatment plant, including Imhoff tank, sludge bed, and disinfecting apparatus	[2] 2.00	2,400
Land		250
Total		21,010

[1] Per foot. [2] Per capita.

The operation of the treatment plant would only require a few hours' attention daily. The cost for labor and materials should not exceed $500 per year.

As Trenton has practically no sewerage system at the present time the item for sewers on the estimate given above should be considered as a collection system rather than an intercepting system and therefore not a cost incident to the installation of a treatment process. On this basis the cost incidental to treatment is given in Table No. 85.

TABLE No. 85.—*First cost and annual charges for Trenton, Mich.—1,200 population.*

	Structures.	Land.	Total.
First cost	$2,400	$250	$2,650.00
Interest at 4½ per cent	108	11	119.00
Amortization	13		13.00
Fixed charges	121	11	132.00
Operation charge			500.00
Total annual charge			632.00
Annual charge per capita			.53

Acknowledgment.—Mr. H. L. Bloomshield, village engineer, rendered material assistance in furnishing maps and making available other information of value for the Trenton study.

AMHERSTBERG, ONTARIO.

The city of Amherstberg, Ontario, is the farthermost downstream municipality on the Detroit River. It possesses no manufacturing establishments of consequence and has had an erratic trend as to growth in past years. The population was 1,936 in 1871, 2,672 in 1881, 2,279 in 1891, 2,222 in 1901, and 2,560 in 1911. There is no apparent reason to expect that it will grow rapidly in the future, and it has been assumed that interceptor provision for 4,000 people and treatment-plant provision for 3,000 people will be ample.

No regular records are kept of the water pumped, but from a statement of the pumping-station engineer as to the number of times the water tank is filled during a day, it appears that the daily per capita consumption is about 165 to 170 U. S. gallons. As this information is of meager nature, and as Amherstberg is a very old city, so that the water mains are probably in a very leaky condition, the interceptor has been designed on an assumed water consumption of 125 U. S. gallons per capita daily, with a sewage contribution therefrom of 100 U. S. gallons per capita per day, to which has been added a ground-water allowance of 1,000 U. S. gallons per acre per day, and a further allowance of 100 U. S. gallons per capita per day to cover drainage which enters the existing sewers from the rural districts back of the city.

The estimated cost of the project is presented herewith, as follows, and includes the cost of a separate sludge-digestion tank, not shown on any of the plates:

TABLE No. 86.—*Cost for Amherstberg, Ontario—3,000 population.*

Item.	Unit price.	Cost.	Total cost.
1,240 feet of 10-inch sewer	[1] $2.00	$2,480	
580 feet of 12-inch sewer	[1] 2.20	1,276	
700 feet of outfall sewer	[1] 2.00	1,400	
Diversion chambers and tide gates		600	$5,756
Pumping station:			
Buildings and pump well		2,000	
Machinery and piping		2,300	4,300
Treatment plant, including Imhoff tank, sludge bed, grit chamber, and disinfection apparatus	[2] 2.25		6,750
Land			250
Total			17,056

[1] Per foot. [2] Per capita.

The existing sewerage system has two outlets, one in Richmond Street and the other in Park Street. There is a suitable site for a treatment plant just south of Park Street, which permits the use of a short interceptor line. The interceptor shown on plate 30 and in profile on plate 31, designed to carry the sewage to a pumping station at this site, follows Dalhousie

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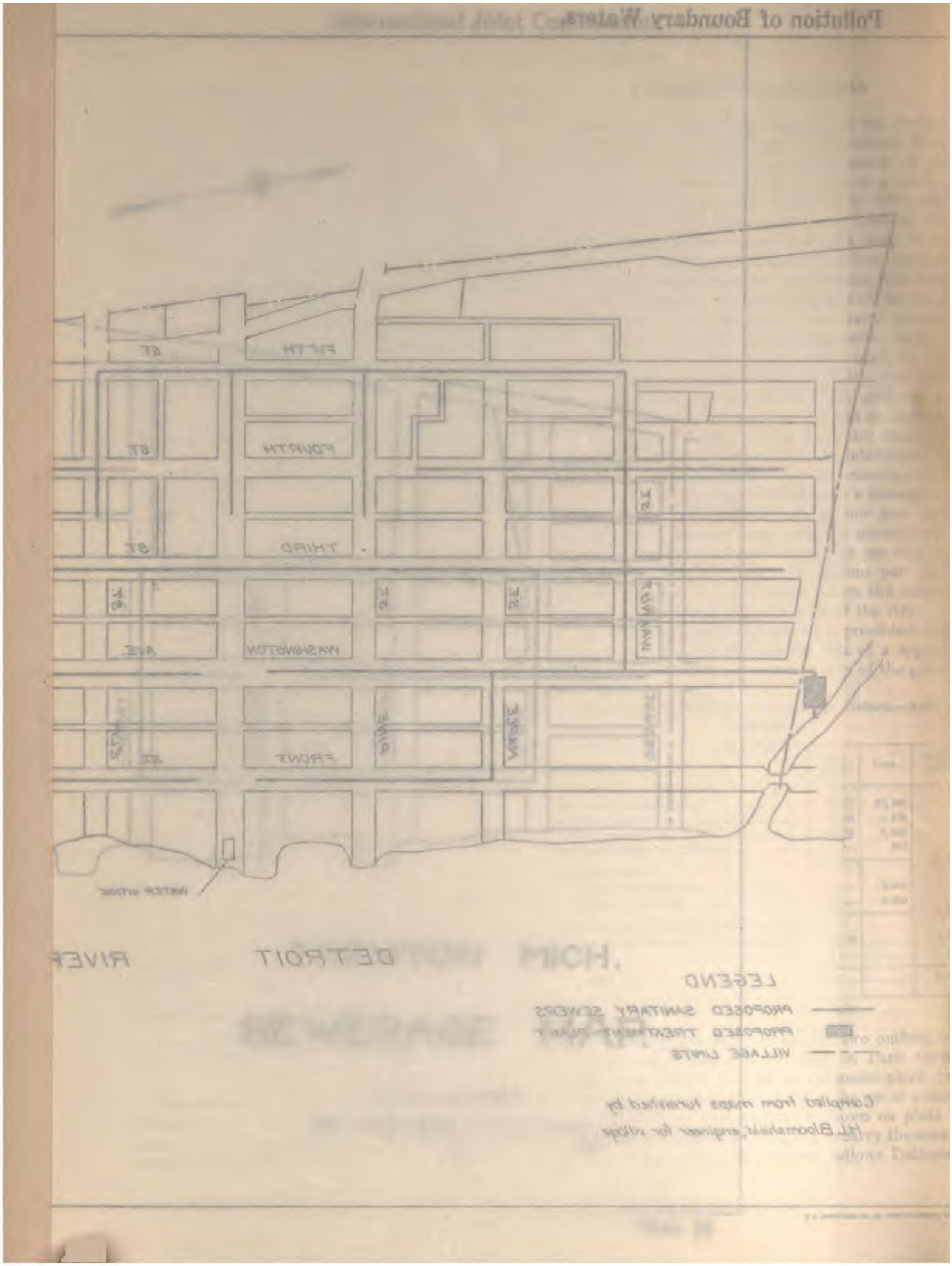

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APPENDIX II.

NIAGARA RIVER DISTRICT.

ENGINEERING STUDIES.
INTERCEPTION AND TREATMENT OF RIPARIAN SEWAGE.

1916.

REPORT OF

F. C. TOLLES, District Engineer.

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INTRODUCTION.

I have the honor to transmit herewith reports upon studies of the practicability and cost of remedying the pollution of Niagara River from riparian sewage.

These reports are designed to furnish the basis for an answer to certain phases of the second question of reference to the International Joint Commission under date of August 1, 1912. They are subdivided into a general Niagara River report, which presents the summary conclusions, and into a series of subreports which furnish the detailed considerations upon which the conclusions are based.

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GENERAL NIAGARA RIVER REPORT.

DESCRIPTION AND SANITARY CONDITIONS.

The Niagara River is a boundary common to the Dominion of Canada and the State of New York. The waters are international in jurisdiction, the line being in midstream and following the Chippewa Channel at the fork about Grand Island.

The river is from 725 feet to 1½ miles wide, is 35 miles long, and connects the Lakes Erie and Ontario. The total fall from source to outlet is 326 feet, of which 167 feet occur in the sheer drop at the Falls and 86 feet in the rapids above and below. The balance is sufficient to give the water a velocity of 3 to 4 miles per hour. Broken as is the river by falls and rapids, navigation is impracticable between Lewiston and Niagara Falls. The depth varies from nothing at the inlet to 200 feet in the lower reaches, and the discharge averages 209,100 second-feet, with a minimum of 153,200 and a flood run-off of 376,700 second-feet.

In addition to serving as an outlet for the vast drainage area tributary to the upper four of the five Great Lakes, Niagara River has a local drainage area of about 1,260 square miles, of which 780 are in the State of New York. Situated along its course are the American cities of Buffalo, Tonawanda, North Tonawanda, and Niagara Falls; the villages of La Salle, Lewiston, and Youngstown; and the Government post of Fort Niagara. On the Canadian side is the city of Niagara Falls, Ontario, the town of Bridgeburg, and the villages of Fort Erie, Chippawa, Queenston, and Niagara-on-the-Lake. Inland on either side there are several small towns and a populous farming country, the bulk of the population, as in the case of the riparian communities, being on the American side. Table 88 gives the distribution and summation of the population.

TABLE 88.—*Population, 1915, Niagara River local drainage area.*

	American.	Canadian.	Total.
Riparian (all urban)	530,331	18,110	548,441
Inland (estimated from 1910 census):			
Urban	46,128	5,770	51,898
Rural	79,976	21,624	101,600
Total	656,435	45,504	701,939

In addition to its natural function as an outlet in the Great Lakes chain, the Niagara River is utilized in part as a means for navigation, and throughout its length as the source of municipal water supplies and as the outlet for domestic and manufacturing wastes. Also along its banks are scattered summer camps and cottages, leading to a further utilization for bathing, fishing, and for pleasure boating. In the lower river is a small fishing industry.

Aside from the development of power at the falls, the present maximum benefit derived from the river is probably that afforded by its character as a source of water supplies and by its carriage of municipal wastes. In this way there are used daily some 175 million gallons, the water supply of 560,000 people, while sewage to the extent of 139 million gallons daily is returned directly, together with an indefinite amount of drainage from an inland population of about 135,000 persons. The river is also the point of disposal for the garbage and refuse of the city of Niagara Falls, N. Y.

As regards the effects of the sewage discharge there are few places on the Niagara River where pollution is noticeable to the point of giving positive offense to sight or smell. At the Canadian Maid of the Mist landing in a pool of slack water odors are at times evident; also at and below the point of discharge of refuse stranded matter is to be observed along the banks, but aside from these instances the velocity and volume of the river discharge are such as to prevent sludge deposits and make nuisances entirely local.

The facts as presented fix the water supplies as the only interests affected by pollution and lead to a consideration of conditions of the river and adjacent territory from this point of view.

The present day (1915) sewage discharge of riparian communities is recorded in Table 89.

TABLE 89.—*Amount of sewage, Niagara River district.*

City.	Sewage, M. G. D.[1]	Per cent of total.
Buffalo, N. Y.	[2] 109.3	78.6
Bridgeburg, Ontario	[3] .5	.4
Tonawanda, N. Y.	3.7	2.7
North Tonawanda, N. Y.	5.4	3.9
La Salle, N. Y.	.2	.1
Niagara Falls, Ontario	4.2	3.0
Niagara Falls, N. Y.	15.7	11.3
Total	139.0	100.0

[1] M. G. D.=million gallons daily.
[2] Does not include sewage now discharged into Erie Canal.
[3] Sewage subjected to subsidence.

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Reference to the general map of Niagara River will show the principal points of discharge and their relations to the various water intakes.

To remedy existing conditions two alternatives offer: (*a*) The discharge of sewage into the river can be stopped; (b) sewage can be treated prior to its discharge.

THE DIVERSION OF SEWAGE.

The removal of sewage from Niagara River can be accomplished only by providing another outlet, and inasmuch as large streams in other watersheds are not available, the ultimate point of outlet must continue to be Lake Ontario. Two methods of diverting the sewage from the river are at hand: (*a*) By the construction of a marginal trunk sewer; (*b*) by means of an open canal.

In either of these cases the American and Canadian sides must be considered separately, and inasmuch as the former involves the greater expense, attention has been devoted chiefly to that side of the river in the discussion which follows.

MARGINAL SEWER.

From South Buffalo to Lake Ontario in a fairly direct line is 40 miles, and, with allowance for necessary detours, it is probable that a trunk sewer would approximate 45 miles in length, in addition to one-half mile of outlet in the lake, needed to secure discharge into deep water. The quantities of sewage to be conveyed are estimated upon an ultimate population of 1,000,000, divided as in Table 90.

TABLE 90.—*Marginal sewer basic quantities, Niagara River district.*

Cities.	Population, 1950.	Maximum rate sewage flow at 450 gallons per capita.			Size, feet.
		Total.		Accumulated cubic feet per second.	
		M. G. D.	Cubic feet per second.		
Buffalo	800,000	360	557.6	557.6	11
Miscellaneous	44,000	19.8	30.6	588.2	11
Tonawanda	15,000	6.75	10.4	598.6	11
North Tonawanda	28,000	12.6	19.5	618.1	11½
La Salle	7,000	3.15	4.9	623	11½
Niagara Falls	100,000	45.	69.8	692.8	12
Lewiston	3,000	1.35	2.1	694.9	12
Youngstown	3,000	1.35	2.1	697	12
Total	1,000,000	450	697	.....	.....

The grade is limited by the total fall between the two lakes, and it may be assumed that the cost would equal that of a 11½-foot sewer built almost entirely in tunnel and up to the Falls below ground-water level. The unit cost is estimated as follows:

Excavation, 7.5 cubic yards, at $2.50	$1
Masonry, 2 cubic yards, at $12	2
	4
Contingencies and appurtenances, 33 per cent	1
Cost per lineal foot	5
Cost per mile	300,00
45 miles at $300,000	13,500,00
Outlet	100,00
	13,600,00

In addition to the main trunk there would be quired local collectors and storm-water overflow tensions, which in the case of Buffalo are estima at $750,000. Thus it is probable that the total of a marginal trunk sewer with connections would be less than $15,000,000.

For purposes of discussion it may be assumed t interceptors to serve a population of 1,000,000, ca ing to separate treatment works, would, on the Am can side of the river, cost about $2,072,000, thus—

Buffalo	$1,60
Kenmore	10
Tonawanda	10
North Tonawanda	50
La Salle	25
Niagara Falls	253
Lewiston	2
Youngstown	20
	[1] 2,072

Treatment works may tentatively be estimate $3.50 per capita.[1]

1915 construction, 700,000 at $3.50	$2,450
1930 construction, 300,000 at $3.50	1,050

The statement then stands:

CONSTRUCTION.

Cost of trunk sewer	$15,000
Cost of treatment works interceptors	2,072
Cost of treatment works (Imhoff tanks):	
1915	2,450
1930	1,050
	5,57
Excess first cost trunk over treatment	9,42

ANNUAL CHARGES.

Trunk sewer:	
Interest on $15,000,000, at 4½ per cent	$67
Maintenance on trunk sewer, 45 miles, at $100	
Depreciation, $15,000,000, 80 years, 4½ per cent	2
Yearly cost trunk sewer	70

[1] See estimates in succeeding portions of report.

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Treatment works:[1]	
Interest on $5,572,000, at 4½ per cent	$250,740
Sewer maintenance, 25 miles, at $100	2,500
Depreciation —	
Interceptor, $2,072,000, 80 years, at 4½ per cent	2,840
Treatment, $3,500,000, 50 years, at 4½ per cent	19,600
Operation (sedimentation and disinfection) 1,000,000 people, at $0.35	350,000
Yearly cost treatment plant	625,680

These figures, while general, indicate a financial advantage in favor of sewage treatment over a trunk-sewer diversion project. In the case of a corresponding trunk sewer for the Canadian side, the present-day disparity might not be so great, inasmuch as with existing treatment at Bridgeburg, and with no sewerage at Fort Erie or at Chippawa, a trunk sewer could be stopped at Niagara Falls.

DRAINAGE CANAL.

In the second possibility offered for collection—that of an open canal—the financial advantages of treatment would be considerably greater than in the first instance, were there not present the possibility of carrying construction and maintenance charges by the development of water power. This possibility is created by the existing difference of elevation between Lakes Erie and Ontario—a total of 326 feet.

The first question to arise in this connection is as to the diversion of water from Lake Erie. This matter is the subject of international treaty, which fixes the permissible diversion on each side of the river. Of the American allowance, there yet remains unappropriated 4,400 second-feet. Also the treaty[2] specifically exempts from the limitation "diversion of water for sanitary or domestic purposes," and in Article VIII gives a priority to appropriations for such use.

It thus appears that there is available 4,400 second-feet of Niagara River water, and if that be insufficient an indefinite balance, the appropriation of which, however, must be primarily dependent upon sanitary needs.

To prevent nuisance from the carriage of sewage in open channels necessitates the addition and admixture of water sufficient to supply proper oxydation of the putrescible content, with a further provision that slowly moving streams also require a prior removal of material capable of settling at velocities equal to or in excess of those occurring in the channel. As generally expressed, the ratio of diluting water to sewage ranges upward from a proportion of 4 cubic feet per second to each 1,000 of tributary population. The Chicago Drainage Canal was designed to carry 3.3 second-feet per 1,000 population, and because of a deficiency in velocity is now affording in the upper reaches considerable trouble from sludge deposits.[1]

In studies relating to the Charles River Dam at Boston, the same question was considered and the conclusion reached that a nuisance is likely to result when the ratio falls below 3½ cubic feet per second per 1,000 population; that with rates between 3½ and 6 cubic feet per second the results are doubtful, and that with more than 6 cubic feet per second per 1,000 objectionable conditions are not likely to result.[3]

In discussion relative to investigations of Ohio rivers, Allen Hazen states that in sluggish streams, or in those carrying some pollution, the required diluting quantity may become 6, 8, or even 10 cubic feet per second per 1,000 population.[3]

Such statements are, however, general, and must be interpreted in the light of several factors, including those of velocity, means for diffusion, temperature, structural features affecting sedimentation, etc. The matter is here presented only in sufficient detail to establish authority for the statement that on the American side alone, in order to properly dilute the sewage from an expected future population of 1,000,000, there will be required a river diversion of not less than 6,000 or 7,000 second-feet, and that even this amount is not certain to avoid nuisance if the sewage receive no prior treatment. Objectionable features, if occurring, would result from the presence of floating matter and from the concentration and subsequent putrefaction of deposits. The first could be obviated by the use of coarse screens which, though inexpensive, would nevertheless require constant attention. Deposits can be avoided only by a prior removal of settleable matter, or by securing such velocities as would prevent settling. Prior removal, while practicable, is the fundamental part of sewage treatment which it is the function of the canal project to obviate. Prevention of subsidence, on the other hand, requires the maintenance of average cross-sectional velocities of not less than 2½ or 3 feet per second, and is of course at the expense of fall otherwise available for power. The second requirement also precludes the interposition of such quiet bodies of water as would result from the creation of storage basins, slips, and the like, for while sludge can be removed and handled without offense from proper tanks constructed for that purpose, it would not be practicable to economically remove sludge from any extensive natural bodies of water.

[1] Does not include economy resulting from deferred construction of treatment works.

[2] Treaty between the United States and Great Britain—Boundary waters between the United States and Canada. Proclaimed May 13, 1910.

[1] Report on Sewage Disposal, Sanitary District of Chicago, G. M. Wisner, 1911.

[3] Report of committee on Charles River Dam, 1903, Appendix No. 5.

[3] See American Sewerage Practice, Metcalf & Eddy, Vol. III, p. 256.

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Although the dilution of sewage to the extent of 6 or 7 cubic feet per second per 1,000 population may, under suitable conditions, render the mixture inoffensive to sight or smell, such water is, of course, not potable, and if discharged into a source of water supplies, may prove a serious menace, a possibility that must be considered in the present instance.

In applying the general project of a diversion canal to Niagara River conditions, it is apparent that while Canadian and American remedial measures must be separated, a channel in either case must approach the shore of the river in order to intercept all marginal drainage. In the absence of a specific project, it is difficult to be satisfied that all conditions are met, but it is apparent that only at the expense of lengthened route, pumping, complicated connections, or incomplete interception of drainage, would it be possible to avoid discharge of the diluted sewage at some point close to the mouth of the Niagara River and, indeed, a thorough study of conditions might lead to a determination that discharge into the river current itself would be essential to adequate diffusion.

In the event of discharge at some point removed from the influence of the main river current, there is a decided possibility that the river would act as a barrier which, while preventing or hindering pollution from crossing the international boundary, would also interfere with rapid diffusion, tending on either side to an increase of littoral pollution. The seriousness of this contamination would depend largely upon local currents and upon winds, but whereas under present and almost ideal mixing conditions the evidences of sewage are quite appreciable 10 miles from shore and are noticeable 15 miles out, it is patent that with restriction of the immediate diffusion field, either the pollution would be more pronounced or else it would be felt to a greater distance from the point of discharge.

On the other hand, to discharge the diluted sewage into the main river current would secure desirable rapid mixing and dilution, but would inevitably bring into discussion the question of pollution crossing the boundary, and while this might not of itself be serious at the present time, developments might later lead to a state of affairs where the pollution would be in contravention of treaty rights.

The territory at the western end of Lake Ontario is at present undeveloped. With the mouth of the Niagara River as a center, Toronto, Hamilton, and Rochester are the nearest important centers of population, being, respectively, 29, 40, and 77 miles distant by water, while Port Dalhousie, at the outlet of the Welland Canal, is 11 miles distant, and Olcott Beach, a summer resort, lies 18 miles from the river mouth. Further development of this territory is not impossible as concomitant with greater utilization of Niagara Falls power in the lower river, but is largely a matter of speculation. On the contrary, it is t expected that the lake shores on both sides of boundary will increase in popularity as a loca for cottages and summer resorts—residential area the character which not only utilize the lake wa for bathing, but are also prone to accept them domestic use without treatment.

The conclusion then of this discussion of the priety of discharging raw sewage into Lake On is that such utilization is not harmonious with p ent nor prospective development of this terri that the discharge of a large volume of diluted sew at no considerable distance from the shore would p ably give rise to local nuisance, increasingly evi with time, and in the event of certain combina of wind and current, might endanger internati rights or possible water supplies, however vag present. Further, that it would be contrary to a h policy of conservation, and while this attitude is ject to the argument that the interests destroyed of less value than those served, the huge cost and m nitude of a canal project, if adopted, would practi commit the cities involved to this form of disp for a long time to come, notwithstanding the dev ment of conflicting interests.

There is, however, another aspect of this m which merits consideration. If, for any reason, t be constructed a canal connecting Lakes Erie and tario—whether for navigation or for power purp or both—it would be possible to so route such a c nel as to facilitate the effective disposal, not of c sewage but of treated sewage. The advantage of a means of discharge lies in the fact that it woul feasible to construct the canal at such levels as to an outlet materially lower than either lake or a above the Falls, thus effecting economy in any pu ing attendant upon treatment works operation.

Also were such a canal built in a manner to i cept both the dry weather and flood flows of str tributary to the river, or in such location as to re the storm overflows from intercepted trunk se it would be a factor in the improvement of the eral sanitary regimen of the Niagara River, and th neither removing nor lessening the need for both age and water treatment, would be in effect added tection to the water supplies of riparian commun

The first of these questions is financial, an largely offset by the possibility that the greater centration of sewage in a canal as compared that obtaining in Niagara River might require more extensive removal of organic matter than w be demanded for the river in order to avoid phy nuisance. Furthermore, there exists the addit though more remote, possibility that less favo conditions of disposal in Lake Ontario, in con tion with proximity to a local water intake,

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necessitate disinfection in excess of that needed for river discharge.

The second point, while worthy of recognition in balancing two projects, in itself has but little weight.

In summary, then, it may be stated:

(*a*) That the diversion of riparian sewage from Niagara River by means of a marginal trunk sewer is not feasible because of the expense.

(*b*) That the collection of a crude riparian sewage into a combined sanitary and power canal, accompanied by dilution with lake water and involving the final discharge of raw sewage into Lake Ontario, is not a proper solution of the problem, because of the creation of nuisance en route, and because of the conditions created at the outlet.

(*c*) That the discharge of treated riparian sewage into a surface canal is both proper and feasible if the treatment be carried to a point at least equal, and possibly superior, to that demanded for river discharge, but that such a project possesses little apparent advantage when coupled with the necessity for preserving it from nuisance and from transgression of international and local rights at the outlet.

It should be noted that these conclusions are based only upon the remedies as affecting pollution of international effect. The merits of any particular solution as between two communities on the same side of the border are not within the scope of this report, except as subsidiary to the major issue.

This chapter of the Niagara River report has dealt with the possibility of meeting the second question of reference by the adoption of diversion works. There remains for consideration the second alternative of remedying pollution through the treatment of the sewage.

SEWAGE TREATMENT.

The early investigations of the Commission were confined to bacterial examinations, the B. coli count being regarded as the index of pollution. The consideration of the potability of water must, in addition, devote attention to turbidity and to the presence of organic matter of suspicious origin.

Of the several riparian communities involved, Buffalo, North Tonawanda and Niagara-on-the-Lake disinfect their water supplies with liquid chlorine; Niagara Falls, N. Y., is supplied with rapid sand filters; Niagara Falls, Ontario, uses chlorine at times; Fort Niagara treats its water; and the balance, including Fort Erie, Bridgeburg, Tonawanda, and Youngstown, use the water untreated. La Salle and Kenmore are supplied by the Western New York Water Co., which treats part of its water and draws the balance from sources other than the river, while the inland city of Lockport chlorinates its supply.

Thus, save in Niagara Falls, N. Y., and La Salle, none of the water receives purifying filtration, the attention being devoted solely to the destruction of pathogenic bacteria. The reason for this lies in the all but occasional freedom of the river water from objectionable turbidity. It is, however, unreasonable to expect that satisfaction with such treatment or lack of treatment can long continue, for the disinfection of water should be regarded as insurance of great value in time of epidemic and to meet occasional contamination, and as an additional reserve safeguard in connection with purification. In the case of a continuously and seriously polluted raw water, treatment is generally adopted to remove organic matter of animal origin, holding in reserve or as a final treatment the application of disinfectants.

It would therefore appear reasonable to predicate the needs for sewage treatment upon the assumption that the purification of water supplies drawn from the Niagara River will be such as will not only destroy pathogenic bacteria reliably and continuously with a minimum of danger through disturbance of apparatus, but will also effect incidental removal of organic matter. This view is important in fixing the requirements for any treatment of sewage, and results from an equilibrium between efficiency and expense of the treatment of both water and sewage, for granted the need for water purification, it becomes broadly economic to devote the greater attention to this phase of the problem, utilizing the treatment of sewage to the extent required to keep the burden on the water purification within bounds which are reasonable and safe. The major premise to this statement is to be found in the universal opinion of sanitary authorities that surface water supplies from inhabited areas are not safe for consumption without purification, while the conclusion has been evaluated elsewhere in this report.

It may be that with such necessity imposed, the different communities may find it advantageous to combine with a view toward drawing their supplies from other sources,[1] but irrespective of this possibility, the problem offered by the second question of reference remains unchanged, viz,—to outline such treatment as will reduce existing pollution of boundary waters to the condition that will be met by such water purification as would be required were all pollution practically removable eliminated from consideration. That statement outlines the purpose of the following discussion.

Considering the problem from the bacterial standpoint, two methods are available for reducing pathogenic germs—(*a*) filtration and (*b*) disinfection.

FILTRATION.

Sewage treatment by filtration is designed primarily to remove putrescible matters which are beyond the

[1] See, for example, pamphlet of New York State Conservation Commission, outlining scheme for impounding the headwaters of Little Tonawanda Creek at Linden.

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scope of screening or of sedimentation. The bacterial removal accomplished in this process, though appreciable, is secondary and irregular. Moreover, its efficiency in this respect is in no wise commensurate with the expense.

Whereas the conditions along the Niagara River demand effective and quantitatively high bacterial removal, they do not require extreme reduction of putrescible contents, thus practically eliminating consideration of any of the several types of filtration.

DISINFECTION.

Disinfection of sewage is possible in several ways, but the most modern and effective method is to subject it to the action of calcium hypochlorite, or bleaching powder. Such a process necessitates means for holding the sewage and chemical in contact for a short period; and if economy and efficiency be objects, there is required in addition the removal of the larger solid particles contained in sewage. This solid matter includes much of the offensive portion of sewage and is in such form as to resist thorough disinfection through resistance to penetration of the chemical. A proper balance of sedimentation and disinfection thus becomes economic, permitting of a reduction of chemical to a minimum.

The choice of remedies is thus narrowed to disinfection accompanied by synchronous or prior treatment to remove solids, or in other words, to disinfection allied to either fine screening, sedimentation, or to both.

FINE SCREENING.

This mode of treatment is more common in Europe than in this country, though attention is now being given to it in several American communities. The process is described by its name and consists in straining the sewage through mechanically driven mesh screens having openings of width of one-sixteenth inch, more or less.

The application of the fundamental principle has taken several forms, the best known in this country being the Riensch-Wurl disc screen, and the Weand screen. The former consists of metal arms covered with slotted bronze plates, the whole rotating obliquely in the sewage channel and lifting from the sewage the screened matter, which is swept from the plates by moving brushes. Units of this type have recently been installed at Brooklyn and at Cleveland.

The Weand screen is a mesh cylinder supported by a metal framework. The sewage discharges into the cylinder as it rotates, the screenings being washed or blown into a trough at the uppermost portion of travel, and from thence conveyed to storage or disposal point.

In each of these types, and in all others, the disposal of screenings is a separate and serious problem. They are made up of paper, fruit skins, fecal ma ter, and other solids forming an offensive produ For ultimate disposal, incineration in combinati with garbage or with fuel offers the ideal soluti and can be accomplished without nuisance. Oth and less attractive modes are burying and reducti in reclamation works where grease is extracted.

SEDIMENTATION.

Sedimentation is the process involved in subjecti sewage to conditions of quiescence, or at least to co siderable slackening of velocity of flow, with cons quent deposit of suspended solids. It is accomplishe in tanks of various dimensions, covered or uncovere and with or without the addition of chemical Tanks of the most modern type, known as Imho or Emscher tanks, are built in two stories so that th settling solids, which fall through slotted openings i the floor of the upper compartment, may digest fr from contact with fresh sewage. The decompos tion of the solid matter in shallow tanks is often t cause of considerable nuisance, both from odors a from the effect of putrefaction products upon t clarified sewage. In Imhoff tanks experience h shown that for some reason incidental to the hydr static pressure of the overlying liquid the process digestion can be accomplished without offense, lea ing a residue which can be successfully remov periodically and dried on sand beds without nuisan The air dried and spadable sludge may be used fill in waste lands, as low-grade fertilizer, or may incinerated.

The clarification of sewage is in itself a compl process of treatment when the object to be obtain is the lessening or elimination of nuisance by a mo erate reduction of the putrescible content of sewa When further reduction is necessary, or when t destruction of pathogenic bacteria is important, cla fication is a process preliminary to other treatme In these studies it is coordinated with disinfecti as a matter of economy and as offering the advanta of the removal of solids.

COARSE SCREENS AND GRIT CHAMBERS.

It is common practice to pass sewage throu coarse screens and detritus tanks in anticipation any other treatment. Such procedure, involving use of bar screens of 1 to 2 inch spacing, remo bulky floating matters which might interfere with operation of subsequent devices; and also takes heavy settleable solids—principally sand—which be handled more economically in this way than other and more intricate treatment. Such pr treatment is particularly desirable when pumping necessary.

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EFFICIENCY AND COST.

It must be strongly emphasized that the sewage of each city possesses individual characteristics which prevent the setting up of general standards. However, it is possible to give typical figures illustrating general efficiency, and these are given in Table 91 by showing the percentage removals of organic matter and of pathogenic bacteria, as accomplished by the different processes.

Costs, too, vary considerably, and to meet this variation there have been prepared estimates of each form of treatment. The data upon which the estimates are based do not apply to any frontier city, but are characteristic of the majority, and include a high average sewage flow of 300 gallons per capita, expensive treatment sites, and the need for pumping. The cost figures are per capita annual amounts, with interest at 4½ per cent and an assumed life of 50 years. To render the list fairly complete and to bring out the relative expense, the more elaborate filtration processes are included.

TABLE 91.—*Niagara River district sewage treatment—Comparative costs and efficiencies.*

Type of treatment.	Per cent removal.[1]		Annual per capita charges.		
	Organic matter.	Pathogenic bacteria.	Fixed.	Operation.	Total.
Coarse screen and grit chamber	0	0	.....	.....	.....
Fine screens with prior coarse screening.	10	15	$0.110	$0.183	$0.293
Imhoff tank—1-hour detention with prior coarse screen and sludge beds	25	35	.080	.147	.227
Imhoff tank—2-hour detention, coarse screen and sludge beds	30	60	.126	.147	.273
Disinfection, fine screens, detention tanks, coarse screen	20	98	.137	.446	.583
Disinfection, 1-hour Imhoff tanks, screens and sludge beds	25	98	.096	.329	.425
Disinfection, 2-hour Imhoff tanks, coarse screens and sludge beds	30	98	.142	.329	.471
Contact beds, coarse screens, 2-hour Imhoff tanks, sludge beds	60	80	1.16	.192	1.352
Sprinkling filters, 2-hour Imhoff tanks, secondary tanks, sludge beds, coarse screens	60	90	.71	.225	.935

[1] In part from Fuller: Sewage Disposal, 1912, p. 741.

The figures given indicate that of clarification processes, fine screening and tank treatment with a two-hour detention period are similar in cost. Screening is ordinarily regarded as cheaper than subsidence, and the equality here shown is due first to the desirability of installing at least two screens, even though one would do the work, in order that some reserve might be at hand in case of breakdown; second and chiefly, the difference is due to the requirement of a mechanic to control and repair machinery. In the case of large plants these differences would be of less moment, and might disappear; and conversely, in a small installation the differences are more outstanding, leading in this report to an elimination of screening as a process of interest to small towns.

When disinfection is added to the foregoing process, fine screening is handicapped by the need for constructing tanks or channels where proper contact between chemical and sewage can be secured. Where there are available long outfalls in which the flow-through period is 20 or 30 minutes, the tanks may be dispensed with. In the case of the Imhoff tank sedimentation, the disinfectant may be applied in the influent channels and the ordinary detention required for subsidence utilized for the contact period.

As to disinfection, the costs betray the fact that more bleach has been allowed for screened than for settled sewage in order to meet the difference in removal of putrescible matter. In this report the allowances have been respectively 7 and 5 parts of available chlorine per million parts of sewage.

The answer to the question of "possible and advisable" remedies for the conditions resulting from existing contraventions of the treaty is offered in the treatment of sewage by clarification and by disinfection. There follow in subsequent sections a study of the detailed applications of such treatment to the different communities concerned.

CONDUCT OF STUDIES AND BASIS FOR DESIGNS.

GENERAL CONDITIONS.

In an investigation of the character conducted thoroughness often becomes subordinate to expediency, but in the present instance it is believed that the speed with which the ground has been covered has not been at the sacrifice of care, and while additional time could be well spent in the making of surveys, gagings, and borings, and in the working out of details, the data collected have been sufficient for the end desired,—viz, to formulate judgment and to report upon the practicability and the cost of remedying the pollution. It is thus that while the findings here presented can not be regarded as a final solution of the problem they are preliminary in nature and can be used to indicate the direction of subsequent work, for it is assumed that in the developments arising from this investigation the towns concerned will utilize competent engineering advice for the work to be done, as the work of the Commission in no sense usurps or replaces the undertaking of studies by the towns themselves.

The towns reported on in subsequent pages have fallen into two classes: those with and those without sewerage.

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In the first case existing sewer records have been searched, and in some cases supplemented by levels, to the end of fixing the locations and elevations of sewers. With these as a basis, and with estimates of present and future sewage flow as fixed by the water consumption, feasible disposal sites have been chosen and necessary collector lines laid out. In the larger cities this has necessitated a study of alternate schemes, with consideration of the economics. Elsewhere the combinations possible have not been numerous, resulting in a quicker sifting to eventual conclusions.

The unsewered towns have been inspected with a view to establishing probable lines of sewerage development, proceeding from this to a choice of disposal sites with consequent fixing of interceptor lengths. The cost estimates offered in these cases are general figures resulting from more detailed studies in neighboring communities.

The conditions obtaining along the Niagara frontier are not favorable to the economic building of sewerage works. The river, with its tributaries, is the universal outlet, this making necessary the construction of marginal sewers in order to intercept all pollution. This not only often requires construction in the most fully developed sections, but also places much of it below ground-water level. Furthermore, the very slight north and south slope of the ground makes proper sewer grades at reasonable depth almost impracticable, and in many cases leads to the introduction of pumped step-ups in the grade. From the treatment point of view the difficulties are ground water and the expense of the land, for in all cases the works have been located adjacent to the river, not only to secure convenient outlet, but also to conserve pumping; this latter feature in all cases making the more costly land the more economic.

The foregoing notes are directly pertinent to all communities above the Falls; below, they do not obtain, but give way to the expense of construction in the rock formation encountered up to the escarpment, and in the case of Niagara Falls, N. Y., to the deep tunnel sewers which are a feature of that city.

In this catalogue of particulars no mention has been made of the high water consumption and consequent high sewage run-off prevalent in all the frontier cities. It is proper to point out that while the large sewage flows encountered do not form an insurmountable obstacle to satisfactory treatment, they do nevertheless increase the cost of any process, and are in a measure responsible for the amplitude of the cost estimates. Such lavish use of water is the direct concern of those paying the bills, but can not in any way be a deterrent to proper treatment, for the cost in excess of that normal to the handling of sewage is but another item in the water bill.

INTERCEPTOR CAPACITIES.

Another point meriting attention is the basis of design for collector capacities. Practice in this respect is not standardized, as will be evident from Table 92, quoted from volume 1 of Metcalf and Eddy's American Sewerage Practice.

TABLE 92.—*Interceptor capacities in various cities.*

[Metcalf and Eddy.]

City.	Ultimate population.	Maximum rate d. w. f. sewage (gallons per capita per day).	Interceptor provision (gallons per capita per day).
Chicago, Ill., North Lake Front:			
Majority report	120,800	180	4,282.0
Minority report	120,800	180	1,540.0
Boston, Mass	600,000	150	258.0
Massachusetts North Metropolitan interceptor	513,000	.....	239.0
Metropolitan Charles River interceptor	157,000	.....	224.0
Metropolitan Neponset River Valley interceptor	213,316	.....	223.5
Metropolitan High Level sewer	986,000	200	300.0
Baltimore, Md	1,000,000	.....	300.0
Providence, R. I	337,000	145	363.0
Paterson, N. J	300,000	.....	250.0
Louisville, Ky	263,550	.....	357.0
Milwaukee, Wis (1889)	562,010	.....	419.0
Passaic Valley sewer project	1,649,440	.....	241.0
Milwaukee, Wis. (1910)	850,000	248–271	350.0
New Bedford, Mass	220,695	125	400.0
Fitchburg, Mass	82,160	.....	432.0
Syracuse, N. Y	410,000	125	375.0
Fitchburg, Mass	87,200	.....	450.0
Fort Wayne, Ind	150,000	150	350.0

Niagara Frontier sewers are all built upon the combined principle; that is, they normally carry only domestic and manufacturing wastes, but in time of storm the strictly sewage flow is augmented by the addition of run-offs from roofs and pavements. This accretion of flow dilutes the normal or dry-weather sewage, but the first wave carries with it much foul matter in the form of dust and street sweepings; also the first rise of water in the sewer serves to wash down solids previously stranded and to scour out the deposits resulting from low dry-weather velocities. The problem, then, is as to how much of this first flow should be diverted, and the solution is obscured by the complex manner and timing of these waves, which depend, among other factors, upon the area and shape of the drainage district, the intensity and duration of the rainfall, and the direction in which the storm moves.

Table 93 records the provision which has been made in the case of Niagara River towns.

STORM WATER DIVERSION.

It will be observed that the margin between average flow and maximum capacity is small. This pro-

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TABLE 93.—*Interceptor capacities, Niagara River district.*

Cities.	Average water consumption, present, G. C. D.	Sewage flow, G. C. D.[1]	
		Average.	Maximum.
Buffalo, N. Y.	324	277	482
Niagara Falls, N. Y.	440	360	[2] 534
Niagara Falls, Ontario	312	373	512
Tonawanda, N. Y.	583	400	600
North Tonawanda, N Y.	452	400	600
La Salle, N. Y.[3]	107	100	350

[1] Includes infiltration.
[2] Nominal; tunnel sewers with capacities greater than shown.
[3] Sanitary system—small town.

portion depends first upon the ratio between average flow and the maximum rate, and it has been found for the large per capita amounts here dealt with that this ratio is small, being for trunk sewers in the vicinity of 1 to 1.5 or 1.6. This fact has been verified, though continued and supporting sewer gagings are much to be desired. The explanation appears to lie in the high basic rate from which a small variation in percentage signifies a really large total amount.

The second factor in establishing interceptor capacity is the proportion of storm water to be accepted, for all run-off in excess of the allowance will pass the collector and reach the river untreated. The table also shows that in the work covered by this report generally and almost universally no specific allowance has been made for storm water as such. This does not mean that none will be accepted, for inasmuch as the interceptors are proportioned to meet the needs of a future population, they provide capacity in excess of present requirements, and the surplus is available for storm run-off. Such surplus, however, will be a decreasing variable and in the end will become practically zero. Another allowance is contained in the fact that if storms of rare intensity be excepted the distribution of rainfall is uniform throughout the day, this making available for storm drainage the difference between the maximum interceptor capacity and the average sewage run-off. Equally important is the high per capita sewage flow for which the sewers are designed, a flow which harmonizes fairly well with present-day water consumption rates, but which, because of added cost due to both water and sewage treatment, it is expected will be materially lessened in the future.

Moreover, it is believed that it is possible to overestimate the importance of accepting any considerable portion of storm run-off. Referring to the specific instance of Buffalo, it is known that the average year includes in the vicinity of 370 hours of rain, or, in other words, that during 7½ rainy months the hours of precipitation are limited to 6.8 per cent of the total time. Further, it is known that during these 370 hours there will fall 21.2 inches of rain, and if, to form a mental picture, it be permitted to place the average hourly precipitation at 0.057 inch, the resulting run-off for a 0.5 impervious coefficient and for a total drainage area of 20,600 acres is 590 cubic feet per second. From the detail report for that city it appears that designs for Buffalo interceptors require a total capacity of 600[1] cubic feet per second for an average 1950 flow of 343 cubic feet per second, thus giving a combined average run-off of 933 second-feet during 370 hours of storm and causing the overflow at such times of 36 per cent of the dry-weather sewage then flowing; and inasmuch as these periods of overflow are limited to 6.8 per cent of the total time, the gross sewage overflow during 7½ months would approximate 2.4 per cent of the total sewage discharged. If, further, there be eliminated all hours during which there is registered a precipitation of 0.04 inch or less, the percentage of sewage overflowed becomes 1.8 per cent of the total.

The looseness of this mode of reasoning is apparent, being based upon flat rates of rainfall and run-off. It is, however, indicative, and when it is recalled that the balance of the annual precipitation occurring during the other 4½ months is very largely snow, which in the latitude of Buffalo does not readily melt and run off in any short time; and when it is further known that some 27 per cent of the annual rainfall occurs as storms of hourly amounts of 0.05 inch or less, the 2.4 per cent overflow factor might be acceptable as an approximate value.

Consideration of the matter in this wise makes evident that the whole problem is one of relative efficiency and economy. Utilizing the data previously presented with a view to decreasing the sewage overflow from 2.4 to 1.5 per cent, it becomes necessary to increase interceptor capacities 20 per cent, which for the larger sizes is equivalent to a similar increase in cost. This in the case of large works is a considerable investment, and at once raises the question as to whether a smaller investment at the waterworks' end would not better accomplish the purpose in view.

It is true that the overflow discharge of sewage occurs at times when tributary streams are bringing to the major stream an accumulation of inland and of rural pollution, and it is also true that it is impracticable to set a proper limit of interception of storm drainage, but it appears probable that the capacities of frontier interceptors as designed are not much removed from the point of equilibrium between cost and accomplishment.

[1] Total 615.6 cubic feet per second; 597.6 for present city area.

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FEATURES OF TREATMENT.

As to the details of treatment, conformity to certain principles has been adopted, viz:

PERIOD OF DESIGN.

Interceptors have been proportioned to meet the needs as of the year 1950, which has been assumed as the ultimate date to which present-day studies can apply with reasonable degree of probability.

Treatment works, excepting grit chambers, have been designed for a capacity adequate for 15 years to come. This period has been made long so as to allow for time consumed in initiative legislation and the work preparatory to construction, thus giving the costs of such works as would be constructed at that time. Grit chambers have been designed on the same basis as the interceptors.

FINE SCREENS.

Sizes have been selected upon the commercial ratings of the Riensch-Wurl type, to care for the average flow, and with sufficient units to insure that in case of the breakdown of one, the balance of the plant will not be subject to more than a 75 per cent overload at times of dry weather flow. The screen house has been proportioned to accommodate one additional screen of the largest size selected.

IMHOFF TANKS.

In the smaller towns fairly shallow tanks have been chosen on account of the high-ground water plane. The type has been either circular or rectangular, according to the ratio between sewage flow and sludge capacity, it being found that circular tanks can be more readily adapted to high per capita flows, although for extensive plants rectangular units with common dividing walls have been found more economic.

The upper compartment has been designed to retain 120 per cent of the average rate of sewage discharge for a period of 2 hours, or for a nominal average detention of 2.4 hours. The percentage used insures that the bulk of the flow will be subjected to sedimentation resulting from the period noted.

Sludge storage has been provided to the extent of either 1½ or 2 cubic feet per capita, the larger amount being used in Buffalo and Niagara Falls, where trade wastes are a factor. The allowances made were deemed sufficient to permit of retention of sludge over the non-drying winter months.

Certain studies have been made of the cost of Imhoff tanks providing one hour's detention. Table 91 gives a general idea of their relative position as regards cost. Such a tank in combination with disinfection provides a period more than sufficient for the action of the chemical, and would also secure an appreciable removal of organic matter. Emphasis has not been placed upon this possibility, because of uncertainty as to the performance of such a tank with the dilute sewages prevalent along the frontier. Experiment only can show the wisdom of its use, and it is suggested only as a possible source of economy should the removal of organic matter prove satisfactory.

SLUDGE BEDS.

For the larger cities, sludge bed estimates have been based upon 1 square foot, net, for every 3 persons. In other places the provision has been 2 square feet for 5 persons, the difference representing an estimate of the probable differences of expert control, leading in the larger installations to riper and better draining sludge.

DISINFECTION.

For tank effluents, calcium hydrochlorite[1] at the rate of 5 parts of available chlorine per million parts of sewage has been allowed, the dose being applied just prior to entry into the tank.

For screened sewage the application has been increased to 7 parts per million to allow for a smaller reduction of solids in this process.

The disinfecting apparatus itself is planned to consist of a masonry mixing tank wherein a 4 per cent solution of bleach will be prepared and later pumped to one or more stock tanks where the solution will be attenuated to a 2 per cent mixture, which is that used for the dose.

INTERCEPTORS.

These have been designed to receive the maximum flow to be expected in 1950. A general minimum velocity of 2½ feet per second has been set, but has been transgressed in several instances where pumping could be avoided by the adoption of a lower velocity. In these cases special construction to secure smooth surfaces has been called for.

The interceptor profiles have been laid out to insure either uniformity of hydraulic grade in the water surface or else so as to preserve a slight drop at changes of sizes and intersections of lateral sewers.

Slight attention has been given to the exact manner of interception, for the devices must be worked out in accordance with local data. One or two special cases have been considered and are described in the detail reports. In general it is expected that a low dam will be placed across the trunk sewer, with an opening upstream thereof connecting to the interceptor. Where grades admit, the interceptor itself, in either original

[1] During the writing of this report there has been some fluctuation in the price of bleach from its previously prevailing market value of $25 per ton. A permanent increase in the figure might be sufficient to justify the use of liquid chlorine in place of bleach, but does not affect the conclusions reached.

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or altered section, can form the dam, which should be set so as to divert the maximum permissible. To compensate for the reduction of section by the dam, it will be necessary to widen the original sewer above and below the point of diversion, this forming the chief expense of the construction. The opening and connection can well be formed of a slotted plate set in the sewer invert in such manner as to be capable of occasional adjustment, or else the opening might be regulated as to size by a float-controlled gate actuated preferably by the water level in the interceptor. Connections of either of these types have been installed elsewhere, and it has been thought sufficient to allow for some similar construction in the estimates, leaving the selection as a matter of detail design.

No particular material has been specified for interceptor construction, as such would probably be fixed by individual city standards. Where ground water is to be expected in troublesome quantity, an effort to retard leakage has been made by allowance for a concrete jacket.

MECHANICAL PLANTS.

Pumping machinery has been selected to meet the maximum rate of flow. No reserve apparatus has been included, but in all cases the units are such as to permit of considerable overload in case of breakdown of one part; and, being designed for maximum rates, it will be possible to install minor repairs without interference to operation.

Electrical equipment has been figured on very generally, owing to the availability of low cost power, and because of the simplicity of construction and operation for small plants where semiautomatic motor control can well be included.

In two instances estimates have been based upon steam power, in order to take advantage of the heat from incinerating plants for the disposal of sludge or screenings. It is expected that coal fuel will be employed, and the operation costs include no allowance for the heating value of either sludge or screenings, the incineration being regarded as a disposal and not as a utilization process.

In most cases the elevations are such as to make necessary the pumping of sludge from the tanks, and to meet this condition it is expected that the air lift will be employed, calling for the installation of an air compressor with suitable piping and appurtenances.

The mechanical equipment has not been the subject of very detailed studies, chiefly because in cost it forms but a small percentage of the total.

SEWAGE FLOW.

The amount of sewage to be handled both now and in the future has been determined in various ways, but chiefly from a study of water consumption. In Buffalo and in Niagara Falls, as representing more involved conditions, the studies took the form of separation into domestic, industrial, commercial, and leakage factors. In the small towns less detail has been observed, the principal reliance being placed upon some careful gagings in Tonawanda and upon harmony with the conclusions from other studies.

The relation between average and maximum flows has been based partly upon the Tonawanda gagings, but chiefly upon the water consumption studies, in this case building up a pyramid derived from the relations existing between average daily, maximum daily, and maximum hourly rates.

Considerable room exists for a closer determination of these sewage quantities, and where given it is with full expectation that they will be checked by independent derivation, preferably from a long series of gagings.

COST AND CONCLUSIONS.

UNIT PRICES.

For construction costs an examination has been made of contract prices in three of the several cities. Buffalo costs, since contracts are let for a lump sum, are difficult of analysis, but the prices herein presented are in advance of those used in that town. Some of the more fundamental prices are given in Table 94.

TABLE 94.—*Approximate unit prices, Niagara River district.*

Item.	Range.	Approximate average.
Excavation, trench:		
Earth	$0.60 to $1.50	$1.25 per cubic yard.
Rock		$3.50 per cubic yard.
Excavation, treatment works, earth.	$0.30 to $2.25	$1.75 per cubic yard.
Brick masonry in sewer		$8.50 per cubic yard.
Concrete masonry in tanks	$6 to $21	$10 per cubic yard.
Vitrified pipe	65 per cent to 75 per cent off list.	
Manholes		$5.50 per vertical foot.
Timber sheeting	$15 to $25 per M feet b. m.	
Steel sheeting		$32 per ton.
Cast-iron pipe		$30 per ton.
Repaving, asphalt and block		$2.50 per square yard.
Buildings	$0.10 to $0.20 per cubic foot.	
Engineering		7 per cent.
Profit and contingencies	15 per cent to 50 per cent.	

The interceptor estimates have been based upon profiles determined from street levels, contour maps, or levels run by commission forces. They are approximate, but should in total be close to correct values.

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Quantities involved in treatment works construction have been determined in similar fashion, but are subject to greater variation in the light of detailed surveys and of borings.

The estimates in all cases are intended to include allowances for consulting engineer service and for royalties and rights of way. Land values for treatment works are also a part of the total.

Operating costs have been based upon assumed attendance for different types and sizes of plants, with provision for supervision, and in the small towns for occasional expert inspection. Common labor has been estimated at $2 per eight-hour day, and mechanical help up to $4.50 per shift in the case of engineers. Power costs are on the scale now charged along the frontier with efficiencies of 70 per cent for centrifugal pumps and 80 per cent for electrical apparatus.

The construction or fixed charges and the operating costs have been reduced to per capita annual amounts upon the assumption of interest at 4½ per cent and of an 80-year life for masonry sewers and a 50-year life for treatment works. Machinery depreciation and repairs have been covered by a 10 per cent annual allowance.

For a detailed application of the general principles, reference must be made to succeeding sections of this report, where each town has been considered to the extent warranted by the data. The summary of these

TABLE 95.—*Niagara River district, cost of sewage treatment—Summary.*

	Construction cost.			Annual cost.			
	Interceptors.	Treatment works.	Total.	Fixed.	Operating.	Total.	Total per capita[1]
Buffalo, N. Y.	$1,561,470	$2,037,281	$3,598,751	$203,457	$187,411	$390,868	
Tonawanda, N. Y.	16,023	54,662	70,685	4,241	6,650	10,891	
North Tonawanda, N. Y.	55,516	74,650	130,166	7,451	8,900	16,351	
La Salle, N. Y.	24,991	13,657	38,648	2,320	1,500	3,820	
Niagara Falls, N. Y.[4]	252,900	283,050	535,950	30,730	28,457	59,187	
Niagara Falls, Ontario	34,600	49,037	83,637	5,108	8,960	14,068	
Lackawanna, N. Y.[1]	.....	4,000	4,000	240	1,200	1,440	
Bridgeburg, Ontario[1]	.....	2,000	2,000	120	500	620	
Fort Erie, Ontario[2]	3,600	10,000	13,600	816	1,500	2,316	
Kenmore, N. Y.[3]	.....	10,000	10,000	600	1,500	2,100	
Chippawa, Ontario[2]	23,800	4,250	28,050	1,680	520	2,200	
Queenston, Ontario[2]	2,500	1,800	4,300	258	500	758	
Lewiston, N. Y.[3]	2,000	3,600	5,600	336	500	836	
Youngstown, N. Y.[3]	15,500	4,500	20,000	1,200	500	1,700	
Total	1,992,900	2,552,487	4,545,387	258,557	248,598	507,155	.....
Average	.....	.....	.....	.....	.....	.....	

[1] Additional to existing treatment works.
[2] When required; no present sewerage (except Kenmore, q. v.).
[3] Treatment (1930) population; interceptors designed for 1950 conditions.
[4] Includes garbage incinerator.

TABLE 96.—*Financial statistics, Niagara River Cities, 1915.*

City.	Population.	Assessed valuation.	Approximate basis of valuation.	Bonded indebtedness.	Water Supply bonds.	Sinking fund.	City tax rate (dollars per $1,000).
			Per cent.				
Buffalo	459,500	$381,667,500	80	$37,870,446	$11,620,383	$4,230,276	
Tonawanda	9,326	5,210,129	85 90	409,411	217,400	14,326	
North Tonawanda	13,521	9,134,630	75	831,700	400,000	.....	
La Salle	2,400	2,052,262	60	70,000	.....	.....	
Niagara Falls, N. Y.	42,334	36,785,780	60	3,001,219	1,266,500	.....	
Niagara Falls, Ontario	11,500	8,641,768	60	802,527	.....	.....	
Lackawanna	16,342	7,456,734	.....	547,203	.....	.....	
Bridgeburg	2,100	1,413,585	100	200,772	39,787	.....	
Fort Erie	1,500	725,000	60	64,000	48,000	.....	
Kenmore	1,800	2,436,343	65	194,502	19,840	.....	
Chippawa	1,200	.....	.....	.....	.....	.....	
Queenston[1]	.....	.....	.....	.....	.....	.....	
Lewiston	800	330,000	70	(2)	.....	.....	
Youngstown	650	300,000	50	20,000	20,000	.....	
Niagara-on-the-Lake	1,400 1,900	783,000	67	65,000	.....	.....	

[1] Part of county.
[2] Special bond issue of $150,500 not included.

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appendices is exhibited in Table 95 which is in essence the conclusion of this report, to wit—that Niagara River pollution can be controlled though not eliminated by clarification and disinfection works in the several towns for amounts not to exceed those shown in the table.

In order to afford opportunity to judge of the financial ability of the different cities to undertake works of the nature described, Table 96 shows the municipal financial statistics as obtaining in 1915.

ISOLATED CONTAMINATION.

The foregoing relates to sewage pollution from riparian municipalities, the investigations having been restricted as in the initial studies to pollution which originates on the frontier, thus neglecting the contamination from inland sources which reaches the major river through such tributary streams as Welland River and Tonawanda Creek. Additional to these is, on the American side, at least, a modicum of contaminating drainage from isolated residences and institutions. Notable among these is Niagara University, situated north of the city of Niagara Falls and discharging into a ravine the wastes from a school population of 300. Two summer hotels at Lewiston, together with several private residences between Lewiston and Youngstown, are also suspected of contributing drainage to a small amount. On the Canadian side no such conditions have been observed, while Grand Island drainage has been entirely neglected.

Detailed studies of this residual pollution are scarcely warranted by the amount involved, except in such cases as that of Niagara University, and can well be deferred until the application of remedies to the other and more aggravated cases of municipal contamination. Effective treatment of residential and institutional wastes can be accomplished by means of tanks and subsurface drains at a cost upward of $400 per installation.

The legislative means of applying remedies and the question of a governing organization for their maintenance and control are considered elsewhere as being outside the engineering aspect of the problem to which this report is limited.

ORGANIZATION AND ACKNOWLEDGMENT.

The engineering studies of interception and treatment for the Niagara River district have been conducted by a district engineer and four assistants, under the direct supervision of the consulting engineer, and in harmony with the work of the district engineer at Detroit. The personnel and period of employment are indicated in the list appended:

Frank C. Tolles, district engineer, March 17, 1915–April 1, 1916.
E. J. Miner, assistant engineer, April 5–May 15, 1915.[1]
H. S. Philips, assistant engineer, July 6–December 31, 1915.
B. F. Perry, assistant engineer, April 17–December 31, 1915.
C. T. Wanzer, draftsman, April 8–December 31, 1915.
H. A. Stevens, clerk, March 25–December 31, 1915.

Particular acknowledgement is due the work of Mr. H. S. Phillips and to the work of Mr. B. F. Perry.

The former, on leave from the Toronto Department of Public Works, initiated the treatment studies and carried through the detailed investigations for Niagara Falls, Ontario.

Mr. Perry, in addition to a critical analysis of Buffalo water consumption, collected the data and prepared the designs, estimates, and report for the city of Niagara Falls, N. Y.

The maps and plans are largely the work of Mr. C. T. Wanzer.

The work actually done could not have been accomplished save for the cordial cooperation of city officials, whose assistance here acknowledged in general has been credited in detail in appropriate places.

It is further a pleasure to record the courteous assistance afforded by Dr. John W. S. McCullough and by Mr. F. A. Dallyn, B. A. Sc., respectively, chief health officer and sanitary engineer for the Province of Ontario.

[1] Forced to resign on account of illness.

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BUFFALO, N. Y.

DESCRIPTION.

The city of Buffalo is situated at the source of the Niagara River, with frontage on that river and also on Lake Erie. It covers an area of 40[1] square miles and possesses a lake and river frontage of about 9½ miles. In population it ranks tenth in the United States and second in the State, having in 1910 a total of 423,715.

The city is primarily a railroad and industrial center, being a focus for several large railroads with extensive terminal yards and dock facilities. Aside from possessing an important transshipping business in grain and coal, Buffalo is the seat of many important industries, including metal working, the manufacture of chemicals, paint and oils, and automobiles, and the handling of meat products, located here because of exceptional transportation facilities by land and water, and because of closeness to supplies of raw materials and to final markets. The barge canal system of New York State, when completed, will also form an outlet for Buffalo freight, and increase its importance in this respect.

Topographically the city is rather flat, the greatest difference in elevation being 120 feet, which represents the gradual fall from a knoll in the northeast corner of the city to lake and river. Geologically the city is built upon the intersection of two beaches formed by the recession of a glacial lake. In the northern part is found an ancient terrace in the form of a limestone outcrop, while the balance and major portion of the city is surfaced with clay occasionally overlaid by sand and gravel. In the southern section a different rock formation appears, with surface outcropping of shale, which slopes to the bed of the Buffalo River. From a construction point of view the geological formation leads to surface limestone rock excavation in the northeastern section, and to occasional rock at moderate depth in the area just north of the Buffalo River. South of the Buffalo River and along Cazenovia Creek shale is encountered, but the greater portion of this flat area offers little but sand and clay, with occasional deposits of quicksand. Elsewhere clay, mostly red, sometimes blue, with some sand, predominates. Ground water is met in the vicinity of lake and river level.

[1] 39.885 square miles, Bureau of Engineering Index on Paved Streets.

DRAINAGE.

The surface drainage which does not directly reach the lake, river, or canal, is taken either to Buffalo River and its branch, Cazenovia Creek in the southern limits, or to Scajaquada Creek in the northern portion. Both of these are flashy streams, affording considerable trouble in time of flood, which, in the case of Buffalo River, reaches at times to 20,000 second-feet, the run-off from an interior watershed of 413 square miles.[1]

The Erie Canal, which starts at the mouth of Niagara River and skirts the western edge of the city, acts as a barrier between the city and Niagara River, and in consequence receives much drainage and also sewage, which otherwise would reach the river. In this terminus of the canal the prevailing current is away from the lake, though certain conditions may cause a temporary reversal of flow.

WATER SUPPLY.

The water supply of Buffalo is derived from the head of Niagara River through an intake crib located well out from shore and connected to the pumping station by means of a rock intake tunnel. This intake is a relocation of an earlier one situated farther downstream; both intakes are shown in the general map of the river accompanying this report. Treatment is limited to disinfection by liquid chlorine applied at the intake pier. From the pumping station the water is pumped through the mains to two balancing reservoirs, the larger of which, at Jefferson and Best Streets, holds somewhat less than a day's supply; a small water tower which is connected to the high level system holds but 350,000 gallons, so that there is practically no storage. Generally the water is clear and palatable, but on a few occasions during the year roiliness is very pronounced, owing to the effect of gales upon the shallow lake. It is possible, but by no

[1] Department Public Works Report, 1903.

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means certain, that filtration may be an eventuality, at least for occasional use.[1]

SEWERAGE.

The waste waters of the city, including domestic sewage, industrial wastes, and the storm drainage from roofs and streets, are carried off through combined sewers to the various bordering bodies of water. The city is quite well sewered, having, in 1909, 507 miles of sewer, equivalent to 1.22 miles per 1,000 of population, or 15.8 miles per square mile of territory drained, as against similar figures of 0.80 and 15.75 miles, respectively, for 15 of the 16 American cities having a population of 300,000 or over.[2] In 1914 the total mileage had become 544.

Reference to the map, plate 36, will show that the city is divided into four major sewerage districts, denoted, respectively, as South Buffalo, Swan Street, Bird Avenue, and Hertel Avenue.

The South Buffalo area covers that territory south of the Buffalo River. It is not very densely populated nor fully developed industrially. It drains through several small sewers to the Buffalo River, a sluggish, tortuous stream, deepened for navigation and connected to the harbor, which latter is an artificial arm of Lake Erie.

The Swan Street district, so termed from its outlet sewer, includes all of the commercial area and a large portion of the industrial section, as well as the subdistrict of Albany Street, which is residential in character. The outlet traverses the center of the city via Seneca, Swan, and Fourth Streets, and discharges into the Niagara River at Albany Street about one mile above the International Bridge. Built in 1885, primarily to secure circulation in the dead end of the Hamburg Canal, the Swan Street interceptor is unable to carry the burden now imposed upon it, and has several relief overflow connections to the former Hamburg Canal, which exists as a covered extension of the Erie Canal. Moreover, between the trunk sewer and the harbor and canal are several areas too low to secure gravity outlet elsewhere, which discharge sewage into both the harbor and the canal. This district, besides being the most important from a sewerage standpoint, also offers the most troublesome obstacles to an adequate collection of drainage and to provisions for the passage of storm-water overflows. Its lateral drainage includes some old sewers regarding which records as to location and elevation are either incomplete, inconsistent, or lacking.

The Bird Avenue sewer district includes the area immediately tributary to Scajaquada Creek, to which the sewer at times overflows. It is quite large and almost entirely residential. The discharge is into the Erie Canal.

The northern portion of the city, together with the adjoining incorporated village of Kenmore, drains to the Hertel Avenue trunk, which carries its dry-weather flow under the canal to a river outlet. The storm water is overflowed into Cornelius Creek, a short distance east of the river.

The Swan Street and Hertel Avenue outlets are submerged; Bird Avenue discharges above mean lake level, while the numerous other smaller lines exhibit considerable variation in this respect.

Table 97 is introduced to exhibit certain characteristics of the areas previously described.

TABLE 97.—*Drainage areas and population (1910), Buffalo, N. Y.*

District.	Area (acres).				Population.	Density, persons per acre.
	Total.	Park, cemetery, and water.	Railroad.	Exclusive of park, cemetery, and railroad.		
Hertel Avenue.....	4,865	185	223	4,457	29,154	6.5
Bird Avenue.....	6,640	1,148	56	5,436	84,194	15.5
Swan Street.....	8,179	171	1,109	6,899	278,004	40.5
South Buffalo.....	5,244	502	977	3,765	32,363	8.6
Total.....	24,928	2,006	2,365	20,557	423,715	20.6

STORM WATER.

Although the sewage of Buffalo is on the combined principle, there are some individual drains too small to carry any great proportion of storm flow. The matter of storm drainage is not of direct interest to this report, but does enter into a consideration of the means of collecting sewage. Table 98, while not comprehensive, includes a few of the more notable examples of small capacity, and for purposes of comparison some of those judged normal by Buffalo standards.

As will be subsequently developed, the total intercepting sewer capacity derived for 1950 conditions is equivalent to 0.025 inch per acre per hour from the whole city area, an amount which is less than all but the last of the sewers instanced in the table. In each case the capacity noted is that flowing full, no account being taken of possible capacity when surcharged.

A study of the proper basis of design for Buffalo storm sewers is outside the scope of the present inquiry. Studies made by the Bureau of Engineering

[1] Mr. Rudolph Hering, in reporting on this subject, is quoted as having stated, "It is my opinion that sterilization by either method (hypochlorite or liquid chlorine) will safeguard the public health at a very much lower cost than the adoption of filtration at this time. As soon as this city is prepared to pay the cost of giving the water at all times an excellent appearance, filtration is the system to be adopted." (Proceedings sixth meeting, Illinois Water Supply Association.)

[2] Bureau of Census, General Statistics of Cities, 1909. Baltimore omitted.

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from data furnished by the United States Weather Bureau lead to a rainfall intensity curve of the form—

$$I = \frac{11}{T^{0.41}} \qquad \begin{matrix} I = \text{Intensity in inches per hour} \\ T = \text{Time in minutes} \end{matrix}$$

as inclusive of all but three storms in a period of 39 years, and with the intensities of these excluded storms falling quite close to the line of the curve. Accumulation curves derived by C. H. Tutton, former assistant engineer, have the equations—

$$I = 0.65\ T^{0.25}$$
$$I = 0.50\ T^{0.25}$$

for "very heavy" and "heavy" rains, respectively.

The meteorological data applicable to Buffalo, as derived from 43 years' record,[1] are:

Temperature: Mean, 46.9°; range, +95 to −14°.
Precipitation, mean, 36.89 inches.
Snowfall, mean seasonal, 75.9 inches.
Prevailing winds, from southwest.

TABLE 98.—*Existing sewer capacities, Buffalo, N. Y.*

Sewer.	Drainage area (acres).	Sewer.			Capacity in inches per acre per hour.
		Size.	Grade.	Capacity c. f. s.[1]	
Michigan Street	121	40 by 60 inches	0.0030	70	0.58
Genesee Street	767	6 feet 6 inches	.00635	370	.48
Ontario Street	508	6 feet	.0036	225	.44
Emslie Street	503	5 feet 6 inches	.0038	180	.36
Breckenridge Street	115	3 feet	.0039	36	[2].31
			.0547	135	[2]1.17
Babcock Street	503	50 by 75 inches	.0020	100	.20
Bird Avenue	6,412	8 feet	.0159	1,000	.16
Bailey Avenue	1,944	7 feet 3 inches	.0025	305	.16
East Ferry Street at Jefferson Street.	2,985	7 feet 6 inches	.0010	210	[2].07
		54 by 81 inches	.0005	62	[2].02

[1] c. f. s.=cubic feet per second. [2] At change in size.

LAKE AND RIVER ELEVATIONS.

Lake Erie has a water area of 9,968 square miles, but generally, and particularly at its eastern end, is comparatively shallow. Its outlet to the Niagara River is over a natural weir or reef, through which exist both natural and artificial channels. The elevation of Lake Erie and its fluctuations from the mean have direct bearing upon sewer capacities and upon the elevations proper for treatment works.

Within the period 1898–1914, inclusive, the automatic gage at Buffalo Harbor has recorded a variation of from minus 5.0 to plus 6.7, with zero at elevation 572.8 mean sea level. In the same interval the yearly means have ranged from minus 1.38 to plus 0.17.[2]

[1] Monthly and Annual Meteorological Summary with Comparative Data of Buffalo, N. Y. David Cuthbertson, District Forecaster.
[2] Bulletin No. 24, Survey of Northern and Northwestern Lakes, April, 1915. U. S. War Department.

A more detailed study of the automatic gage record indicates not only the extreme changes recorded above, but also that within narrower limits the lake surface is exceedingly mobile, with larger rapid changes in accordance with wind and other meterological conditions, and with consequent seiches covering zones of varying amplitude for indeterminate periods of time.

To illustrate, for the period 1906 to October, 1915, inclusive, there is shown in Table 99 the average number of days per year when the lake reached any given stage. The table generally does not include those changes which were of less duration than one hour, or did not exceed the given stage by more than 0.1 foot, unless there occurred a slight rise coupled with long duration. This classification was designed to exclude those variations estimated as too slight or of too short duration to materially affect elevations at treatment works sites.

TABLE 99.—*Lake Erie stages, period 1906 to October, 1915.*

Stage.	Average number of days per year reached.	Stage.	Average number of days per days reached.
579	0.2	575.5	3.1
578	.4	575	5.0
577	1.1	574.5	8.0
576	2.2	574	18.0

[1] Derived from Automatic Gage Records: U. S. Engineer Office, Buffalo, N. Y. Maj. L. V. Frazier, engineer officer.

Table 99 is not comprehensive, and for detailed studies should be amplified by recourse to the automatic records which are obtainable back to 1899. It does illustrate the frequency of variation.

Niagara River as the outlet of Lake Erie is subject to an increase of discharge following lake rises, but, owing to the pronounced slope of the water surface, the consequent variation in level is neither uniform nor so pronounced. The question of these water surface curves has been carefully studied by the International Waterways Commission in connection with proposed regulation of Lake Erie by means of a submerged weir in the Niagara River at or above the outlet of Welland River. Table 100 is abstracted from the final report of the Commission.[1] The compensated stages are those computed to result from the construction of the weir.

The total discharge of water from Lake Erie is 211,200 cubic feet per second, which includes a flow of 1,000 cubic feet per second through Erie Canal and 1,100 cubic feet per second through Welland Canal.

[1] The final report of the International Waterways Commission upon the proposed dam at the outlet of Lake Erie. (S. Doc. 118, 62d Cong., 1st Sess.)

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TABLE 100.—*Natural and compensated stages of Niagara River.*

[International Waterways Commission.]

	Distance from Buffalo Light.	Mean stage.		Low stage.		Flood stage.	
		Natural.	Compensated.	Natural.	Compensated.	Natural.	Compensated.
Buffalo:							
Buffalo Breakwater Light	0	[1] 572.60	572.99	570.00	570.51	579.18	579.29
Albany Street	12,500	568.34	569.25	565.97	567.20	574.33	574.57
Ferry Street	14,000	568.14	569.18	565.83	567.16	574.00	574.29
Austin Street	21,700	567.36	568.52	565.23	566.68	572.76	573.09
Tonawanda Island	64,900	565.91	567.62	563.91	566.05	570.98	571.53
La Salle Landing	93,000	564.16	566.48	562.42	565.41	568.57	569.39

[1] Mean lake level, equivalent to minus 3.30, city datum. Bulletin No. 24, Survey of Northern and Northwestern Lakes, gives mean surface 572.55, 1860-1914.

TREATMENT SITES AND COLLECTOR.

The items to be considered in connection with the selection of treatment sites are proximity to sewer outlets, availability of suitable point of discharge, remoteness from residential sections, and the area and cost of land obtainable.

So far as known, the existing sewer outlets of Buffalo total to 82 and extend along a water frontage of about 10½ miles. Table 101 shows a subdivision of these according to the point of discharge and to site.

TABLE 101.—*Number of sewer outlets, Buffalo, N. Y.*

Point of outlet.	10-inch to 22-inch.	24-inch to 57-inch.	Over 60-inch.	Total.
Erie Canal	14	19	3	36
Niagara River	.....	.....	2	2
Buffalo River and tributaries	23	16	5	44
Total	37	35	10	82

Some of these outlets, including 11 noted as discharging into the canal, are in reality overflows carrying but little if any sewage; others are relatively unimportant.

An examination of the sewerage map, Plate 36, discloses a subdivision of sewerage into main groups as follows:

(*a*) A northern group consisting of three main systems—Swan Street, Bird Avenue, and Hertel Avenue—discharging within a distance of 2¼ miles.

(*b*) A miscellaneous assortment of drains in South Buffalo with no definite system as a center of discharge.

(*c*) Between these two groups a number of widely scattered sewers, none important by itself, and generally serving some small marginal river area.

Such an arrangement leads tentatively to a decision in favor of two treatment sites, one in the vicinity of Bird Avenue as requiring interceptors of a minimum size, and the other at some central point in South Buffalo.

The only alternative to the centralization of sewage at two major works is either a combination into a single plant, or else the multiplication of treatment works up to a maximum equal to the number of sewer outlets. The first possibility has been reviewed with conclusions to be presented hereinafter, but the alternative leading to the construction of numerous, or at the best, of several plants, has not been studied very seriously for several reasons.

1. To obtain the advantages of locating sewage-treatment works at reasonable distances from residential and commercial districts, the choice of sites is limited. This restriction is particularly applicable to a number of sewers located in the center of the city.

2. The multiplication of plants, while securing a saving in the construction cost of intercepting sewers, and in pumping operation, is at the expense of economy in both the construction and operation of treatment works. This excess is found not only in an increase of land required, and in the duplication of pumps, tanks, screens, etc., but also in extra labor, additional overhead charges, and as regards disinfection, in lack of economy in applying the chemical to small flows.

3. Many plants if located economically from the interceptor viewpoint would be situated to discharge into sluggish water, with consequent necessity for a higher removal of organic matter than would be required otherwise.

These reasons have appeared to warrant adhesion to the original plan of reasonable centralization, particularly as the total cost of intercepting sewers needed for consolidation of the sewage is relatively small in comparison with the total cost of the system.

Further study of the matter of disposal sites is possible only in combination with a study of the means and cost of collection.

COLLECTORS.

In all there have been outlined some seven projects for the collection of sewage, of which two relate to the possibility of treating all the city sewage at one point.

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In the presentation which follows it will be understood that none of those described is a complete system of collection, there having been eliminated a number of local and marginal lines which are common to all.

TREATMENT AT SINGLE SITE.

Owing to the preponderance of sewage now discharged below the city water intake, the assumption has been made that any single plant would be located in that section, and specifically on or near Squaw Island, which is the focus of three of the four existing main drainage divisions.

It is this project that was treated in the 1912 report of Hering and Gregory to Mr. D. E. Knowlton, upon the availability of Squaw Island as a site for sewage disposal works for the city of Buffalo. The following excerpts are from that report:

> In our studies we have assumed that the sewage from South Buffalo would be treated at and disposed of from Squaw Island. In order to accomplish this it would be necessary to pump the sewage from South Buffalo under Buffalo Creek and up into some sewer either existing or which would have to be built, through which the sewage would find its way to the pumping station or to the pipes leading to Squaw Island. This method of disposing of the sewage of South Buffalo would not be a difficult matter, and in many ways it would be simpler than to build independent sewage disposal works for South Buffalo alone.
>
> We have not gone into the relative merits of the two methods, as we consider that either would be feasible.
>
> * * * * *
>
> In conclusion we would say that as the result of our studies, we are of the opinion that Squaw Island affords an excellent site for the location of sewage disposal works for the city of Buffalo.

PROJECT I.—PLANT AT SQUAW ISLAND.

(*a*) To collect the sewage of South Buffalo by gravity to the existing pumping station at Hamburg Street, thence lifting to the present Swan Street interceptor, with extension of the latter to Squaw Island.

(*b*) To divert from the Swan Street interceptor the sewage now tributary thereto in order to render it free to accommodate South Buffalo drainage; this to be accomplished by the construction of a paralleling interceptor of somewhat similar size.

(*c*) To intercept from Hertel Avenue and carry south to Squaw Island.

PROJECT II.—PLANT AT SQUAW ISLAND.

Similar to Project I, except with provision for a smaller paralleling interceptor than is there called for, supplying the deficiency by utilizing the present Swan Street interceptor as a force main.

TREATMENT AT TWO SITES.

Projects involving treatment at two sites include the construction of works at Squaw Island to care for the sewage of Swan Street, Hertel Avenue, and Bird Avenue, and in addition provide for the local treatment of South Buffalo sewage.

In choosing possible situations in South Buffalo the most attractive from the collector cost standpoint is one involving location at or near Buffalo River in the vicinity of Abbott Road. To anticipate certain objections to this site a second has been tentatively fixed in the general vicinity of Tifft and Hopkins Streets.

PROJECT III.—PLANTS AT SQUAW ISLAND AND ABBOTT ROAD.

(*a*) To extend the existing Swan Street sewer to Squaw Island and to construct a duplicate of the main sewer of such capacity as to accommodate the whole sewage flow in this district.

(*b*) To intercept the sewage from Hertel Avenue and carry to Squaw Island.

(*c*) To collect South Buffalo sewage for treatment at Abbott Road and Buffalo River.

PROJECT IV.—PLANTS AT SQUAW ISLAND AND ABBOTT ROAD.

(*a*) To extend the existing Swan Street sewer to Squaw Island and to relieve this sewer at its upper end by diverting to South Buffalo the subdistricts of Bailey Avenue, Babcock Street, Fillmore Avenue, and Emslie Street.

(*b*) To intercept and carry Hertel Avenue drainage to Squaw Island.

(*c*) To collect the sewage of South Buffalo to junction with the Swan Street diversion at Abbott Road and Buffalo Creek.

(*d*) To supplement the lower end of the Swan Street sewer by a duplicate up to Carolina Street, to be built at a future date.

PROJECT V.—PLANTS AT SQUAW ISLAND AND TIFFT STREET.

Similar to Project III, with South Buffalo treatment at Tifft Street and Hopkins Street instead of at Buffalo River.

PROJECT VI.—PLANTS AT SQUAW ISLAND AND TIFFT STREET.

Similar to Project IV, with South Buffalo treatment at Tifft Street and Hopkins Street instead of at Buffalo River.

PROJECT VII.—PLANTS AT SQUAW ISLAND AND TIFFT STREET.

(*a*) Extension of Swan Street interceptor to Squaw Island, with a duplicate interceptor to Genesee Street and future extension thereof to Michigan Street.

(*b*) To divert from Swan Street the subdistricts of Bailey Avenue and Babcock Street.

(*c*) To collect the sewage of South Buffalo and in conjunction with the diverted Swan Street sewage to treat at Tifft Street and Hopkins Street.

(*d*) To intercept the Hertel Avenue sewer and carry to Squaw Island.

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Rough estimates of the cost of these various projects have been prepared upon the basis of $4[1] per lineal foot per foot of diameter for masonry sewers, and $2.50 in the case of pipe sewers, these being unit figures obtained from some detailed estimates of similar lines. The results are shown in Table 102.

TABLE 102.—*Comparative costs of collector projects, Buffalo, N. Y.*

Project No.	Length.	Cost.	Relative rank as to cost.	Cost ratio, with IV as unity.
	Feet.			
I	67,700	$1,851,000	7	1.81
II	68,400	1,716,000	6	1.68
III	52,200	1,454,000	3	1.42
IV	50,100	1,023,000	1	1.00
V	61,200	1,615,000	5	1.58
VI	61,800	1,443,000	2	1.41
VII	61,300	1,561,000	4	1.53

As has been pointed out, the costs in Table 102 are not absolute; they are relative, omitting several items which are common to all the projects, and in addition neglecting the important pumping plant operation, which is not constant, but which can be allowed for in a comparison of any two.

The figures given show a first-cost saving in the case of Project IV, which utilizes the existing Swan Street sewer to the limit of its capacity, with treatment at Squaw Island, and which relieves that sewer by diverting a portion of its tributary area to South Buffalo for treatment with South Buffalo sewage at Abbott Road. This project also involves the discharge of treatment works effluent into Buffalo River, which at Abbott Road is a channel 140 feet wide and about 12 feet deep, forming an artificially deepened arm of Buffalo Harbor. The drainage area of the Buffalo River and its tributaries has been given at 413 square miles, but there exist no data as to normal or minimum run-off. In field investigations the commission engineers have been unable to observe any measurable velocity in the river at its channel section, but crude measurements at the Cazenovia Park Dam of Cazenovia Creek indicate that a total dry-weather flow of not more than 40 second-feet from the whole area must be expected at many times during the year. Under the terms of Project IV the stream should be prepared to accept treated sewage up to a 1930 average discharge of 100 second-feet, and to insure absence of nuisance under such conditions would necessitate a very high degree of treatment. This treatment would probably take the form of filtration, and estimating the excess construction cost of this process at a minimum of $12,500 per million gallons daily, $800,000 would be added to the cost of the South Buffalo installation. This amount, added to the interceptor cost as given, is sufficient to render the total larger than that required for Project VI, which accordingly has been favored as offering the most economic solution of the problem.

[1] Compare with unit cost of Table 134.

Project VI is similar to Project IV, except that the treatment works effluent is taken to the harbor. A study of the ability of harbor waters to absorb and dilute treatment works effluent took the form of short time current-meter measurements at the south and middle breakwater entrances. In each case the results were positive and definite, indicating a total movement of 40,000 second-feet from the lake to the harbor under the conditions then obtaining. The velocity off Tifft Street was recorded at 0.9 feet per second. The lake at the time the gagings were made stood at elevation 572, that at the upper end of the lake at Amherstberg being about 572.7; wind was from the southwest and strong, and the lake choppy.

HARBOR OUTLET.

More elaborate studies of local currents, conducted by Dr. George E. Fell during May and June, 1903, are described with charts in the Journal of the American Medical Association.[1] These experiments consisted of a series of float determinations of littoral currents undertaken in connection with the effect of Smokes Creek pollution upon waters proximate to the Buffalo water intake, Smokes Creek being a small stream which carries the sewage of Lackawanna and empties into the lake 1½ miles south of the south harbor entrance. Dr. Fell, who was formerly United States assistant engineer at Buffalo, showed that under conditions then obtaining the currents from even a considerable distance from shore were positive and definitive in tending toward and entering the south and middle entrances; that opposite the Buffalo River mouth there was some movement outward, but that this water, together with the balance of the harbor water, converged toward the American shore to the extent of justifying the conclusion that littoral currents did not reach the immediate vicinity of the water intake as at present located.

These experiments confirm the conclusion derived from the investigations of the Commission that there is in the harbor a movement of water sufficient in amount to absorb the treated sewage from South Buffalo. Also they attempt to go further and establish as a fact that littoral currents, and consequently harbor waters, do not reach the waterworks intake. These observations did not cover many variations of meteorological conditions, and it is now known that the eastern end of the lake may for a time be maintained at a higher elevation than that of the western or inlet end. Such conditions are presented in the

[1] Currents at the easterly end of Lake Erie and Head of Niagara River. Journal of the American Medical Association, Sept. 3, 1910.

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1896 Report of the United States Deep Waterways Commission.[1] Irrespective of what this may mean as to the disturbance of general lake currents, it signifies an occasional reversal of local currents, which at Buffalo may cause the polluted water of the harbor to reach the intake. This, together with drift of harbor ice, are the conditions exceptional to those established by Dr. Fell's observations.

The direct water distance from Tifft Street to the intake is 4 miles, and were the current direct at a velocity of 1 foot per second, a time interval of 6 hours would be necessary for the passage of material from an outfall at Tifft Street to the intake, where the water supply disinfectant is applied.

Decision in favor of a South Buffalo site has been reached upon several grounds—

(1) The treatment contemplated includes chemical disinfection capable of destroying 98 per cent of the pathogenic bacteria.

(2) Evidence exists to the effect that only on occasions does harbor water reach the Buffalo intake.

(3) Much, though not all, of the sewage which a South Buffalo plant would treat is now discharged raw into the Buffalo River, and apparently exerts no continuously adverse influence on the water supply.

(4) An effluent at Tifft Street is no closer to the water works in time than is a plant at Squaw Island to the intakes of Tonawanda, North Tonawanda, Lockport, and Niagara Falls.

(5) The existing treatment of Buffalo water is designed for and is adequate to destroy occasional and attenuated contamination.

FACTORS OF DESIGN.

POPULATION.

The population forecast necessary for the determination of future sewerage needs has been based upon percentage increase curves derived from each of two groups of cities over the same period of time.

Group 1 includes Cleveland, Rochester, Syracuse, Albany, and Buffalo, cities designed to reflect geographical conditions.

Group 2 includes Chicago, Philadelphia, St. Louis, Boston, Pittsburgh, Baltimore, and Buffalo, cities chosen to fix any relation between size and rate of growth.

National census returns from 1840 to 1910 were plotted for each of these groups in curves having as abscissae the years, and as ordinates the percentage increase for the decade previous. The different curves in each group were combined into a smooth average curve which was projected graphically to the year 1950.

[1] See also Wind Velocity and Fluctuations of Water Level on Lake Erie. Weather Bulletin No. 262, U. S. Department of Agriculture, Weather Bulletin J.

With the percentage increases fixed for group 1 a group 2, those for Buffalo were interpolated by t proportion existing between the average populatio for 1910. These, with the resulting population figur are also shown in Table 103.

TABLE 103.— *Population increases.*

	Group 1.	Group 2.	Buffalo.	Resul Buff popu tio
Average population, 1910	288,000	944,000	423,715	42
Projected percentage increase for decade ending—				
1920	22.5	16.0	21.0	51
1930	20.0	12.5	18.5	60
1940	17.5	10.0	16.0	70
1950	15.0	7.5	13.5	80

On plate 33, in addition to the projections Groups 1 and 2, as applied to a population of 423,7 there are exhibited the performances of Group 2 cit after they had passed the 1910 population mark Buffalo. These are shown for comparison only, a do not enter into the forecast save as they appear Curve 2.

The final figure of 800,000, representing an aver population density of 39 per acre,[1] is high, and is intended for the actual population to be expected 1950, but is that figure which, in conjunction w judiciously selected sewage flow units, will render sewers of size adequate to all needs within the per of design. Also it will compensate to a reasona extent for unavoidable errors in the distribution population as resulting from unforeseen stages in city development.

CITY DEVELOPMENT.

In order to effect a distribution of the total popu tion among the several drainage districts, use has b made of a United States Census enumeration distr map prepared by the Bureau of Engineering, and the ward figures obtained from the State cens Various groupings of these data have been made eliminate occasional changes in ward boundaries, have resulted in the derivation of varied rates of crease for different sections of the city. The det are not shown, but the gross results are exhibited subsequent tabular statements of sewage quantities.

Allowance for drainage other than domestic involved an industrial survey, which was conduc by first spotting on a map a large number of classi industrial establishments listed in the 1913 Indust Directory of New York, supplementing this wit number of field inspection trips arranged to cut city by sections, and to trace out water and rail tr facilities. The results are given in Table 104.

[1] 32 per acre of whole city area; 39 per acre of inhabited area.

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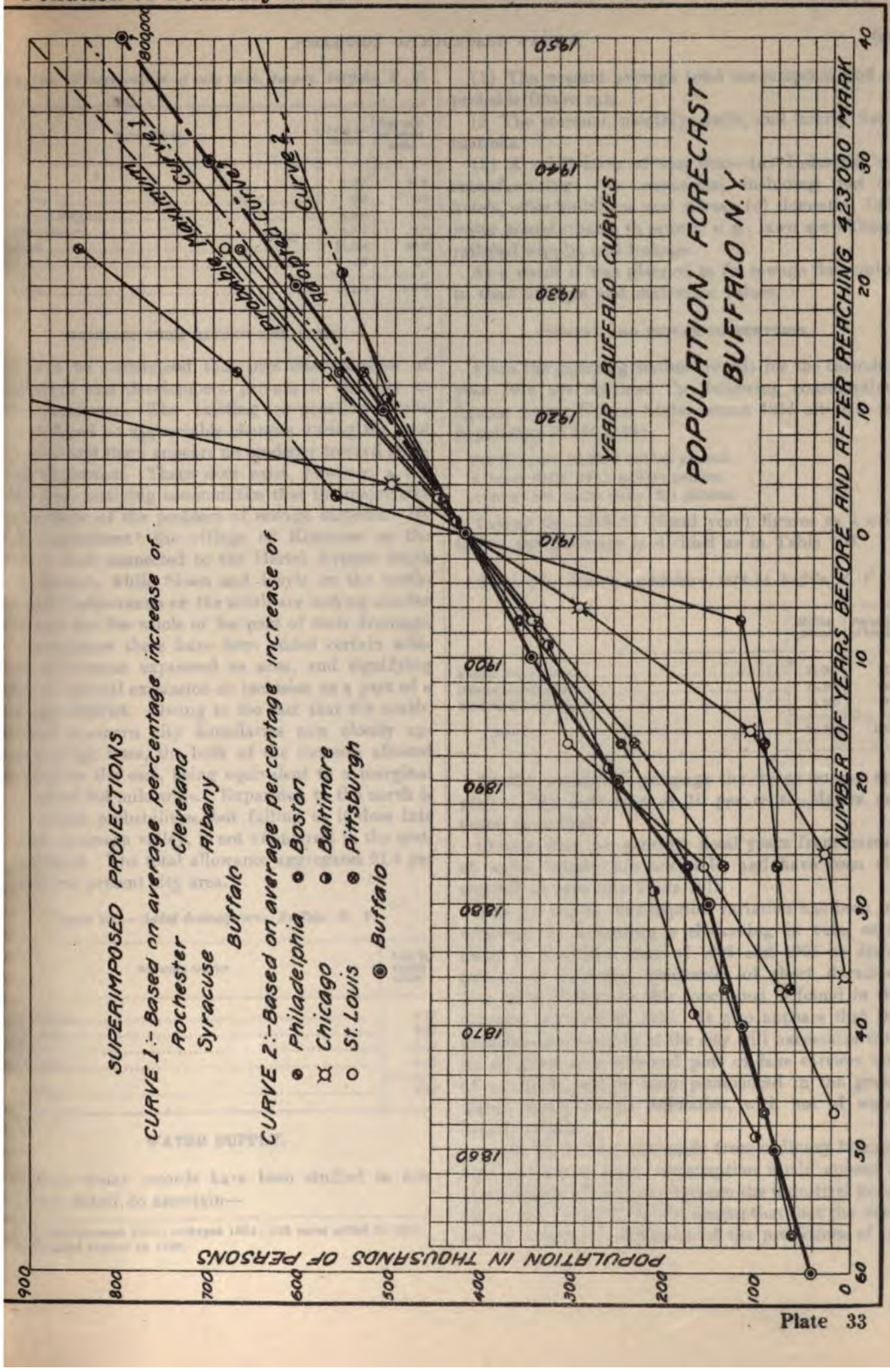

Plate 33

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dustrial and commercial consumption, though any deduction from such ratio must, of course, be tempered by allowance for the character of industries.

Table 108, which exhibits data from United States Census Bureau reports, gives for certain cities, selected at random, the 1910 population, the 1909 "total persons engaged in industry," and the ratio between the two. The cities cited cover a wide range of conditions, and all have lower per capita rates of water consumption than Buffalo.

TABLE 107.—*Water consumption, Buffalo, N. Y.*

Fiscal year.	Average consumption M. G. D.[1]	Maximum day's pumpage M. G.	Minimum day's pumpage M. G.	Average saved by waste and leak service M. G. D.	Number of services.	Number of meters.	Population.	Per capita consumption, gallons daily.
1872	8.841							
1875	10.489						[2] 134,557	78
1880	16.370						155,134	105
1885	26.607							
1890	47.517						255,664	186
1895	93.287					275		
1898	89.064	136.515	87.891		63,284	994		
1900	98.962	150.091	92.569		65,625	1,142	352,387	281
1903	116.810	175.192	108.522		67,531	1,348		
1905	149.592	206.334	115.599	4.0	69,414	1,686	[3] 376,587	397
1906	143.754	191.122	116.715	4.0+	70,585	2,001		
1907	144.397	188.092	119.826	2.0+	71,687	2,413		
1908	135.483	197.673	119.554	3.9	72,882	2,620		
1909	132.825	175.372	114.168	5.6	74,104	2,928		
1910	132.779	175.711	99.311	3.4	75,741	3,255	423,715	314
1911	134.927	175.393	106.880	7.2	77,260	3,459		
1912	139.581	184.100	102.790	8.8	79,309	3,702		
1913		189.062	105.280		81,062	4,020		
1914	143.336	200.291	120.371	20.0	83,878	4,052	[3] 454,113	316
1915							[4] 459,500	[5] 324

[1] M. G. D.=million gallons daily. [2] New York State census. [3] U. S. Census Bureau estimate. [4] New York State census, unofficial. [5] Calendar year 1914.

This table is not in itself conclusive, excluding as it does railroad operation and probably also grain transshipping, but it does indicate that Buffalo is no more essentially industrial than are other cities of its size, and hence that the high water consumption is not primarily due to the intensity or to the character of business.

TABLE 108.—*Industrial and total population.*

City.	Total population, 1910.	Industrial population, 1909.[1]	Ratio total to industrial.
New York	4,766,883	680,510	7.0
Chicago	2,185,283	356,954	6.12
Philadelphia	1,549,008	294,498	5.26
St. Louis	687,029	104,587	6.58
Cleveland	560,663	98,686	5.68
Pittsburgh	533,905	79,625	6.71
Detroit	465,766	95,841	4.86
Milwaukee	373,857	68,933	5.43
Cincinnati	363,591	72,488	5.01
Newark	347,469	69,986	4.97
Buffalo	423,715	61,246	6.92

[1] Thirteenth Census, vol. 8, p. 92 et seq.

The fact is that the large consumption of water in Buffalo is due primarily to the low cost ($0.02 per thousand gallons) and nothing short of an increase in the price of the water itself, following filtration, or in the cost of disposing of it in the form of sewage, may be expected to cause a return to normal rates.[1]

It is recognized that the general tendency, even under meter control and reasonably high rates, is toward a small per capita increase, but such a tendency is applicable only to normal conditions, and the present instance, with correlated facts, is held to warrant an assumption of future per capita decrease. Specifically the consumption has been projected to a total of 221.6 million gallons daily in 1950, which, with the population of 800,000, gives a gross per capita rate of 277 gallons daily.

PERIODIC FLUCTUATIONS.

The daily pumpages for the calendar year 1914 have been compensated to allow for fluctuation in the level of the balancing reservoir. The result is exhibited in plate 34, on which are also plotted the precipitation and mean temperature graphs. The facts outstanding from these diagrams are the equable summer use of water and the quick response of the consumption to a lowering of the temperature below freezing. To

[1] Although in 1914 but 4.8 per cent of the services were metered, 31 per cent of the total supply, or 97 gallons per capita daily, were registered in this way.

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segregate the fluctuations, monthly summaries of industrial, commercial and domestic have been made to the extent shown in Table 109.

TABLE 109.—*Abstract of meter records, 1914, Buffalo, N. Y.*

Use.	Extent.	Total M. G. D.	Per cent of total consumption.
Industrial	211 large establishments	17.5	
Commercial	44 hotels, department stores, and office buildings.	2.4	
Railroads	All	6.5	
Domestic	46 residences of different classes	.046	
Total		26.446	18.5

Monthly plottings of Table 109 consumptions, together with the totals for high and low water service districts, indicate clearly that the bulk of the winter rise occurs in the low service district, and that it is not due to railroads or to industrial plants. In the low service district, which generally covers that area south and east of Genesee Street,[1] the prevailing residences are of medium or of low class, in many instances without cellars, and housing the greater part of the foreign elements of Buffalo's population.

TABLE 110.—*Characteristics of hourly record days, Buffalo, N. Y.*

Date, 1914.	Day of week.	Average consumption M. G.[1]	Temperatures. Mean.	Maximum.	Minimum.	Precipitation.[2]
Summer days:						
Aug. 8	Saturday	151.1	74	83		0
28	Friday	140.7	64	69		0.06
Sept. 6	Sunday	123.5	67	72		T.
26	Saturday	133.5	53	61		0
Winter days:						
Dec. 12	do	140.0	28		24	T.
18	Friday	172.0	23		12	0
26	Saturday	181.5	8		2	T.

		Average hourly.	Maximum hourly.	Ratio.
Average consumption M. G. D.:				
Whole year	147.1	6.13		
"Summer time"	141.0	5.88		
Typical "summer" curve	142.4	5.94	7.07	$\frac{7.07}{5.88}=1.2$
Typical "winter" curve	178.1	7.42	8.45	$\frac{8.45}{7.42}=1.14$

[1] M. G.=million gallons.
[2] From Monthly Meteorological Summary, U. S. Department of Agriculture, Weather Bureau.

More detailed studies of the consumption are most conveniently made by excluding the low temperature rates, which have been considered separately. Thus by deducting the subtotals for December, February, and March, the yearly average is reduced from 147.1 to 141 million gallons daily.

Hourly variations have been developed from the records of seven days. These days have been chosen to avoid any sudden changes in meteorological conditions, and this precaution, coupled with the necessity of securing complete hourly records, has limited the field.

Smooth curves have been superimposed upon the daily graphs to exhibit typical curves applicable to both "winter" and to "summer" conditions. The latter shows a maximum hourly rate which is 119 per cent of the average for the curve, or 120 per cent of the total "summer-time" hourly average. This relation is typical, but misses many high peak days and hours. Plate 35 shows the curves, while Table 110 includes data relating to the days considered.

The maximum rate of 120 per cent is typical, not only of the consumption, but also of the run-off to sewers, provided there is no loss between. Also it is applicable only to large districts, though if these be large enough the overlapping of time factors of flow may cause a peak from one subarea to synchronize with a descending or ascending portion of the curve from another. In the case of the Swan Street interceptor, this diminution amounts to 5 per cent of the average of the maximum rates at the outlet.

The ratio of 120 per cent is smaller than that which generally obtains, and only for the maximum day does it approach the 150 per cent figure often noted. This condition may be attributed to a high basic rate, which includes abnormal leakage, and which in minor degree reflects a disproportionate commercial or industrial use of water.

SUBDIVISION OF USES.

Industrial.—Industrial water consumption to the extent of 17.5 million gallons per day has been abstracted from meter records, which are available for the larger consumers only. The New York State Industrial Directory gives a measure of the workmen employed in the metered establishments, and, by applying the resulting per capita amount to the total number of workers, it is estimated that present-day industrial consumption may be set at 29 million gallons daily.

A number of industries, including all those for which water consumption data were secured, have been spotted upon a map to define five present and typical industrial areas. The known water consumption in each area has been totaled and increased by 65 per cent, as being the increase from known to total industrial consumption. The results, with conclusions, are exhibited in Table 111.

[1] At the time the studies were made the high service district and and low service district were not interconnected.

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TABLE 111.—*Subdivision of industrial water consumption, 1914, Buffalo, N. Y.*

No.	Drainage district.	Industrial characteristics.	Water consumption M. G. D.		Area, acres.	Gallons per acre per day.	Units allowed G. A. D.[1]	
			Known.	Total.			Present.	Future.
1	Hertel Avenue	Metal and automobiles; large plants					5,000	7,500
	Bird Avenue	Small metal working	1.422	2.347	560	4,194	5,000	7,500
2	Swan Street	Meat packing	2.818	4.65	670	6,940		
3	do		1.367	2.256	390	5,785	8,000	12,000
4	do	Chemical and soap	1.410	2.328	465	5,010		
5	do		1.311	2.163	280	7,730		
	South Buffalo						5,000	7,500
	Total		8.328	13.744	2,365	5,810		

[1] G. A. D.=gallons per acre per day.

These units applied to measured areas give the following summary, in which a per capita allowance has been added to insure wide distribution, and thus embrace numerous laundries, restaurants, small hotels, etc., which use water in excess of a domestic allowance.

TABLE 112.—*Total industrial water consumption, Buffalo, N. Y.*

Present, 1914.			Future, 1950.		
Amount.	Unit gallons per day.	Total M.G.D.	Amount.	Unit gallons per day.	Total M.G.D.
2,827 acres	5,000	14.1	2,827 acres	7,500	21.2
1,238 acres	8,000	9.9	1,238 acres	12,000	14.9
450,000 population	10	4.5	800,000 population	10	8.0
		[1] 28.5			44.1

[1] As against 29 M. G. D. previously derived.

Commercial.—The use of water by hotels, stores, office buildings, and the like has been fixed arbitrarily. The meter records of the 44 hotels, etc., previously summarized with a total of 2.44 million gallons daily, are for establishments which fall within a small area. Applying this area to the total, there results $\frac{2.44 \text{ M. G. D.}}{72 \text{ acres.}}$ or 34,000 gallons per acre per day. On the other hand, extracting certain of these situated on Main Street between Seneca and Huron Streets and estimating the percentage of the area involved, there results a rate of 63,000 gallons per acre per day as the present rate applicable to the principal shopping and office building district.

The units set have been rates of 40,000 and 20,000 gallons per acre per day as the future and present average consumption, each applied to the same area—to the future commercial district of 568 acres outlined upon the industrial map.

Domestic.—Attempts have been made to segregate industrial and commercial utilization of water, to which may be added a known metered amount of 6.5 million gallons daily as that consumed by all the railroads. The total of these three items is 46 million gallons daily.

A study of domestic rates from the meter records is attended by the difficulty that such are limited to the larger consumers, or, in other words, to high-class residences. Forty-six of these have been abstracted, and in the case of 18 have been supplemented by house-to-house canvasses to give Table 113.

TABLE 113.—*Domestic water consumption, 18 residences, Buffalo, N. Y.*

Month, 1914.	Gallons per capita daily.	Percentage of average rate.
January	87	52
February	90	54
March	90	54
April	110	66
May	107	64
June	258	155
July	406	243
August	449	269
September	135	81
October	116	70
November	78	47
December	77	46
Average	167	100

The average of 167 gallons per capita daily is inclusive of lawn sprinkling, which in Buffalo is quite extensive. Deduction of this allowance has been effected somewhat arbitrarily by dividing the gross into 38 gallons for sprinkling and 129 gallons per capita per day for all domestic uses. The latter figure can not properly be applied to the whole city, but a reasonable reduction to the average may be secured by employing the relations given in Table 114.

TABLE 114.—*Relative domestic water consumption.*[1]

Type of residence.	Ratio to average.	Type of residence.	Ratio to average.
Apartment houses	1.82	Middle-class dwellings	1.00
First-class dwellings	1.59	Lowest-class dwellings	0.44

[1] Derived from Table 47, vol. 1, Metcalf & Eddy's American Sewerage Practice, as quoted from the March, 1913, Journal of the New England Water Works Association.

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The Buffalo quantity has been identified as belonging to "First-class dwellings," and in consequence its amount is 159 per cent of the average for the whole city. The resulting average is 80 (81) gallons per capita daily.

The method of establishing this domestic rate eliminates main leakage, but includes waste of water or lavishness in use. It is quite possible that the waste included may be reduced, but meters, if installed, are really no check at prevalent rates, and it further appears probable that the activities of the waste and leak service of the bureau of water will be confined to the grosser industrial and line leakage losses. For these reasons the future rate has been set at 75 gallons per capita, which embodies a small decrease, in conformity to the plan previously described.

Water not returned to sewers—*Lawn sprinkling.*—In the subdivision of the domestic consumption, 38 gallons per capita daily were set aside as due to lawn sprinkling. Considering the class of residences for which the meter records were available, and recognizing that in some sections this use of water is negligible, it is believed that an allowance of 20 gallons per capita per day during three months is fairly applicable to the entire population.

This figure, which is equivalent in total to 9 million gallons daily during the sprinkling season, it is difficult to authenticate. However, referring to plate 34, the first week in June, representing, perhaps, the opening of the sprinkling season, shows rather abrupt changes in consumption, amounting to 8 or 10 million gallons daily. It is also characteristic that during the summer a rainy period is followed by a drop and subsequent increase in consumption of from 4 to 9 million gallons daily. Recourse to hourly rates is not conclusive, for while between the hours of 4 p. m. and 7 p. m., August 8 shows an increase of 3 million gallons over the consumption for September 26, this amount diminishes when the normal difference between the rates of the two days is eliminated as due in part to other causes.

However, if none of these considerations serve to establish a definite sprinkling allowance, they do not vitiate that assumed, and may be regarded as supporting an amount proximate to the summer figure of 20 gallons per capita per day, or 5 gallons per capita per day throughout the year.

Railroads.—The railroad use of water is definitely fixed by bureau records at a total of 6.5 million gallons daily. Circular letters to the railroads established the fact that 82 per cent of this is used for locomotive tenders, and is hence not returned to sewers. This is equivalent to 11.8 gallons per capita.

In establishing the units, the present consumption of 6.5 million gallons daily has been extended to 10 million gallons daily as the future amount. This increase is not quite proportional to that in population.

Leakage.—Under previous headings the following particular consumptions have been segregated from the whole:

	Million gallons daily.
Industrial	29.0
Commercial	11.4
Railroads	6.5
Domestic	36.0
Sprinkling	2.3
Sum	85.2

The total is 141 million gallons daily, leaving 55.8 million gallons daily to be attributed to waste and leakage. Examination of the night flows of the "summer" day curves of plate 35 shows a variation of from 76 to 83.5 per cent of the day's average as representing the minimum hourly rates. Published records,[1] which of course include what might be termed normal waste and normal leakage, generally fix the minimum night flow at about 60 per cent of the average, and if this rate be applied mathematically to the minimum and average hourly rates for the five days between August 8 and December 12, there results waste and leak figures of from 57.8 to 77.8 million gallons daily, if the waste be uniform throughout the day.

The only possible conclusion from these data is that the previous allowances for useful consumption have been liberal, and that the resulting waste and leak figure of 55.8 million gallons daily—nearly 40 per cent of the supply—is a quite conservative estimate. It is pertinent to here quote the experience of Niagara Falls, where pitometer surveys led to the opinion that over 30 per cent of that city's supply is "unaccounted for." Also, as far back as 1894, Mr. L. H. Knapp, in referring to the 1894 per capita consumption of 252 gallons daily,[2] estimated 70 per cent of this amount as wasted.

No subdivision of the total amount of 55.8 million gallons daily is feasible, but to give a working hypothesis, 50 per cent has been ascribed to each of the losses; that is, 28 million gallons daily is regarded as leakage from mains, and the balance as waste. The leakage, if distributed over the whole system, is equivalent to 48,000 gallons per mile per day.

TABLE 115.—*Age of water-distribution mains, Buffalo, N. Y.*

Age.	Per cent of total.
Over 45 years (inherited from private company)	5.8
Over 40 years	15.0
Over 30 years	28.5
Over 20 years	72.4

Total mileage, 1914, 579.9.
Abandonments, 1914, 1.3 per cent.

[1] See American Sewerage Practice, Metcalf & Eddy, vol. 1, p. 177; Public Water Supplies, Turneaure and Russell, 1904, p. 30.
[2] Figures quoted from Transactions American Society of Civil Engineers, Sept., 1895.

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'It is apparent that the figures offered are pure speculation, but they, together with the others in analysis of the water consumption, are reproduced to present all the data at hand, in order that their influence upon the final result may be determined.

SEWAGE UNITS.

Of the total water consumed, a certain portion does not reach the sewers.[1]

TABLE 116.—*Water consumed but not delivered to sewers, Buffalo, N. Y., 1914.*

Item.	Gallons per capita daily.
Lawn sprinkling	5
Railroad locomotive use	[1] 10
Retained in manufacturing	10
Leakage—lost	40
	65

[1] Derived at 11.8 gallons per capita daily.

The figures in Table 116 are applicable to 1950 conditions. The item "retained in manufacturing" has been determined from a series of circular letters[2] sent to large industrial users of water, while the "leakage—lost" represents an estimate of the proportion of the total leakage which seeps away, or which may be included in the ground water infiltration figure which forms a part of the total sewage quantity.[3]

The industrial use of water is generally limited to a period of 10 to 12 hours, but some manufacturing processes, including some of the larger users, are continuous, or nearly so. Table 117 exhibits the influence of this condition in proceeding from the water consumption units to those for sewage flow.

[1] Water from wells and from the river, amounting to 33.5 M. G. D., has not been included because the greater portion is returned to the river.

[2] A summary of the returns is as follows:

Industry.	Number of establishments.	Consumption M. G. D.	Retained percentage.	
Brewing	8	1.05	22	
Chemical	9	9.98	5	
Meat packing	3	1.60	26	Data unsatisfactory.
Metal manufacturing	7	6.33	2	Data fair.
Ice manufacturing	6	1.13	19	One concern only.
Railroads	19	3.34	82	

[3] Water service pipes and sewer connections are often laid in same trench.

TABLE 117.—*Derivation of industrial sewage units, Buffalo, N. Y.*

Water consumption, future (Table 111).	Estimated period of run-off hours.	Resulting gallons per acre per day.	Retained in manufacturing at 10 G. C. D.[1]	Sewage flow, 1950 rate.
7,500 gallons per acre per day.	12	15,000	1,800	13,000 gallons, (13,200) per acre daily.
12,000 gallons per acre per day.	16	18,000	2,200	16,000 gallons (15,800) per acre daily.
10 gallons per capita per day.	12	.....	.....	20 gallons per capita daily.

[1] G. C. D.=Gallons per capita daily.

The commercial unit of 40,000 gallons per acre per day, being in itself quite arbitrary, has been arbitrarily increased by 50 per cent to a run-off of 60,000 gallons per acre per day. Such a rate apportions somewhat less than one-third the total to hotels, which discharge sewage over a longer period than do office buildings and stores.

The domestic run-off has been increased in the ratio previously established for the relation of maximum to average of the whole water supply, viz, 120 per cent, which, applied to present and future rates of 80 and 75 gallons per capita, gives rise, respectively, to 96 and 90 gallons per capita.

Winter consumption.—The analysis presented being based upon a derived "summer" average water consumption, there remains to consider the influence of the winter time increase.

A study of the monthly consumption totals has shown the bulk of the winter use to lie largely within the limits of the low service district, and a comparison of the curves for high and low service indicates that of the total cold weather run-off, 60 per cent can be ascribed to that district.

Plate 34, the log of daily pumpage for 1914, gives a maximum day's total of 204 million gallons; previous studies have been based upon a rate of 141 million gallons daily; the transformation is best shown in equation form, bearing in mind that Plate 35 of the the hourly variation shows the maximum hourly cold weather use to be 114 per cent of the average,[1] and that the low service population as of 1914 is estimated at 207,000.

204—141=63 M. G. D., maximum day's winter time increase

63 M. G. D.×60 per cent= 38 M. G. D., total of maximum day's increase in low-service district.

38 M. G. D.×1.14=43 M. G. D., maximum rate of winter time increase in low-service district.

43 M. G. D.÷207,000=209 gallons per capita—capacity required for low-service winter maximum rate.

[1] See Table 110.

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Table 118 shows the number of days during 1914 to which the different rates of water consumption apply, and may be accepted as typical. It is derived from Plate 34.

TABLE 118.—*Water consumption, 1914—Number of days at rate shown—Buffalo, N. Y.*

Consumption M. G. D.	Number of days to and including rate shown.	Per cent of year.
120	2	.....
130	25	.....
140	114	31
145	212	58
150	273	75
160	306	84
170	325	89
180	341	93
190	357	97
200	362	99

From Table 118 it has been decided to make such allowance as would include 97 per cent of the days, relying first upon the fact that such discharge occurring only on days of low temperature is at a time when ground water infiltration is low, and also upon the fact that plate 35 of the hourly variations shows the major winter increase as occurring at times of other than maximum flow, leading to the conclusion that should provision for this element of the sewage flow be insufficient to a small degree, the resulting overtopping of weirs and diversion to storm outlets will be limited to in reality but few hours during the year. Pursuing the arithmetical process previously applied, with a substitution of 190 for the maximum of 204 million gallons daily, we obtain a requirement of 162 gallons per capita per day as that needed to provide capacity for the cold weather surplus, and this has been secured by adding to the previous per capita units an allowance of 135 gallons, which includes the 164 gallons needed for the winter flow, and an arbitrary readjustment of the domestic rate to compensate for the difference between the use of water in high and low service districts. In brief, the winter increase is largely confined to the low-service district, which also includes that population normally most sparing of water; on the other hand, while the high-service district is responsible for a relatively small amount of the winter increase, it is lavish in the normal use of water, hence in giving to each the same flat increase in per capita flow the previous domestic unit has been unbalanced to the point demanded by the estimated relative consumption in the two districts.[1]

[1] As will be seen in Table 120, the sewage allowance computed upon a per capita basis totals to 309 G. C. D., of which 162 and 90 G. C. D. represent the winter excess allowance for low and for high service districts.

The foregoing figures relating to industrial and commercial uses are average consumptions increased in rate so as to occur within the estimated period of discharge, but with no allowance for peak run-off. This condition is very generally observed in the average or inclusive sewer gaging curves of commercial areas, and to some extent in industrial areas; and the larger the district the more prominently does the condition appear, leading in the case of such large districts as obtain in Buffalo, to a practical elimination of the vagaries of maximum rates, which in small sewers may well reach amounts two and one-half to three and one-half times the average. Conclusions of this nature would not be warranted in the absence of confirmatory data, but these have been secured by a series of rough gagings made by means of water level observations at times of maximum flow, and applied to the hydraulic properties of the sewer. Table 119 shows the comparison between the measured values and those computed from the sewage units. The latter are exclusive of the winter flow allowance, except in the case of Swan Street, where the levels are cold weather readings which have been met by averaging the summer and winter maxima as representing an approximation of conditions.[1]

TABLE 119.—*Measured and computed sewage flows, Buffalo, N. Y., 1915.*

Sewer.	At—	Sewage, cubic feet per second.		
		Computed.	Measured.	
Seneca Street	Bailey Avenue	15	20	
Do	Babcock Street	18	30	
Do	Emslie Street	61	61	
Fillmore Avenue	Eagle Street	29	27	
Genesee Street	Niagara Street	20	26	High velocity, difficult to measure.
Bird Avenue	Total	34	29	
Swan Street[1]	Total	154	141	Allowing 27 cubic feet per second through gates at Hydraulic Street.

[1] From Bureau of Engineering series of levels in Swan Street sewer.

The tabulated results, while not startling in their agreement, are held to justify the application of the units to large areas.

Ground water infiltration.—The amount of ground water leakage into sewers is extremely variable,[2] with practical range of from 10,000 to 200,000 gallons per mile of sewer per day, depending not only upon the condition of the sewer and its position, but also upon the season of the year.

[1] Cf. Table 124 for maximum value.

[2] For a compilation of figures see Transactions, American Society of Civil Engineers, vol. 76.

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For Buffalo have been assumed rates of 25,000, 50,000, 80,000, 90,000, and 100,000 gallons per mile per day, applied to different areas according to elevation and soil conditions. By means of measurements of typical sewered areas in the different districts the leakage per mile of sewer has been converted into leakage per acre of tributary area as being in more convenient form for the purpose in hand. The resulting figures have been rounded off, giving units of 1,000 and 1,850 gallons per acre per day, which generally are applicable to Hertel Avenue, Bird Avenue, and Swan Street districts in the first instance and to South Buffalo for the larger allowance, the departure from this classification being in the case of the Swan Street area, some of which is low lying.

Outside areas.—Allusion has been made to provision for area politically external to the city. This area, amounting to 8.43 square miles, it is assumed will be sewered, if at all, upon the separate system, thus making a provision of 6 cubic feet per second per square mile ample.

The summary, Table 120, is offered to show the present average water consumption and its projection to future use, together with the conversion of both present and future amounts to maximum sewage flow units. The totals of this table show a relation between maximum sewage flow and average water consumption of 149 per cent for 1914 and 164 per cent for 1950.

It should be noted that the sewage units are derived from analytical studies, and embody several assumptions which are justifiable only from a lack of positive data. The more direct method of sewer gagings was not feasible in the present instance, but their undertaking would be presupposed as a condition prior to entering upon detailed studies.

It is also pertinent to here emphasize the intimate relations between the questions of water supply and of sewage disposal. These items, often considered separately, are but phases of the single subject, with sewage treatment as the completion of the process. Allied in fact, these questions should be coupled in a proper accounting of the total cost of the service rendered, and it should be realized that an extravagant[1] use of water is not fully accounted for when water rates are paid, but that the conditions are directly reflected in a certain excess cost of sewage treatment.

TABLE 120.—*Water and sewage units.*

	Water consumption.				Maximum sewage flow.			
	1914		Future.		1914		Future.	
	Unit.	Total M. G. D.	Unit.	Total M. G. D.	Unit.	Total M. G. D.	Unit.	Total M. G. D.
Industrial:								
2,827 acres	5,000 G. A. D.	14.1	7,500 G. A. D.	21.2	9,000 G. A. D.	25.4	13,000 G. A. D.	36.8
1,238 acres	8,000 G. A. D.	9.9	12,000 G. A. D.	14.9	11,000 G. A. D.	13.6	16,000 G. A. D.	19.8
450,000 persons	10 G. C. D.	4.5			20 G. C. D.	9.0		
800,000 persons			10 G. C. D.	8.0			20 G. C. D.	16.0
Commercial: 568 acres	20,000 G. A. D.	11.4	40,000 G. A. D.	22.7	30,000 G. A. D.	17.0	60,000 G. A. D.	34.1
Railroads		6.5		10.0	4 G. C. D.	1.8	4 G. C. D.	3.2
Ground water:								
15,192 acres							1,000 G. A. D.	15.2
5,365 acres						[2] 15.0	1,850 G. A. D.	9.9
Leakage		28.0		30.0				
Domestic:								
450,000 persons	80 G. C. D.	36.0			96 G. C. D.	43.2		
800,000 persons			75 G. C. D.	60.0			90 G. C. D.	72.0
Waste:								
450,000 persons	62 G. C. D.	27.8			74 G. C. D.	33.3		
800,000 persons			50 G. C. D.	40.0			60 G. C. D.	48.0
Sprinkling:								
450,000 persons	5 G. C. D.	2.3						
800,000 persons			5 G. C. D.	4.0				
Winter allowance:								
450,000 persons		6.1			135 G. C. D.	60.8		
800,000 persons				10.8			135 G. C. D.	108.0
		146.6		221.6		219.1		363.0
Outside city limits (8.43 square miles)					[3]		[3]	(32.8)
Per capita allowance							309 G. C. D.	
Total per capita			277 G. C. D.				454 G. C. D.	

[1] The report of the committee on water consumption, American Water Works Association, gives statistics for 145 American cities. The average consumption of these is 135 gallons per capita daily. In the list given but four towns use water more liberally than does Buffalo, and of these four one only, Tacoma, Wash., is of large size.

[2] Estimated.

[3] 6 cubic feet per second per square mile.

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The plea, then, is not that the use of water be unduly restricted, but that the matter be brought to the attention of consumers by making the water rates to include a fair proportion of the sewage-disposal costs, thus enabling the consumption to automatically seek an economic balance.

COLLECTION—PROJECT VI.

From the data at hand, and with the units of sewage flow established, it becomes possible to resume the study of sewage interception, rendering in some detail a description of the different lines with statements of areas drained and resulting sizes, together with estimates of cost. The routes as described are those which accomplish the purpose desired, are direct, and where possible avoid obvious obstacles; they should be regarded as tentative and to be interpreted in the light of underground conditions, paving programs, etc.

SOUTH BUFFALO DISTRICT.

Main interceptor.—Starting at the disposal site, at Tifft and Abby Streets, the main stem of the South Buffalo interceptor is shown in Abby Street to Abbott Road; thence running easterly in Abbott Road and northerly in Bailey Avenue and Wightman Avenue to a possible prolongation of Oliver Street; thence to a crossing of Cazenovia Creek near South Park Avenue, following the east bank of Cazenovia Creek and through Pomeroy Avenue to Seneca Street. At this point the main line ends. An extension is shown in Jordan Place to its terminus, thence crossing Buffalo Creek and the Pennsylvania Railroad right of way to a line which follows the easterly margin of the latter to Mineral Springs Road, with a terminus at South Ogden Street.

The main line as described serves to intercept the 54-inch sewer at Boone Street, small sewers at Heussey, Kimmel, and South Park Avenues, and diverts the two 30-inch laterals in Seneca Street, as well as providing outlet for several subtrunk sewers.

The extension of the trunk is designed to collect the sewage from South Ogden Street and to give future outlet to several small sewers on the north side of Buffalo Creek. This extension calls for 6,100 lineal feet of sewer, at a cost of $40,000, whereas it would be possible to construct a small tank plant in the vicinity of South Ogden Street outlet for not to exceed $10,000, which amount, joined to capitalized operation, is such as to prove the local plant more economical in first cost, and upon a parity with interception in annual charges. In time, however, the present-day population of about 2,000 is expected to increase to 4,200, and to include in addition sewage from area outside the city, at which time the annual charges for local treatment would exceed those for interceptor extension. For this reason, but principally because of the administrative objections to small plant operation, and because the point of discharge is not in itself entirely satisfactory, the plans and estimates present the interceptor as the preferable solution, but with the understanding that financial considerations might render the local plant temporarily expedient.

Branch interceptors.—Branch interceptors have been provided at South Park Avenue on the west side of Cazenovia Creek, and along the easterly margin of the same stream. The latter is intended to receive the flow from several small sewers discharging into the creek, and has been stopped at Hammerschmidt Avenue in the belief that the short sewers in Ryan and Geary Streets can be reversed to connection with Seneca Street, as are others in this vicinity. Levels are needed to establish this point.

The west side branch has been made to extend up South Park Avenue to interception at Cumberland, where a connection to the prolongation of the Cumberland Street sewer may be effected. The Cumberland Street sewer, if enlarged at its upper end, can also serve to collect the dry-weather flow from Meriden Street. The arrangement outlined is designed to maintain levels at the highest practicable point, and enables the collection of sewage with a minimum of present day construction. The enlargement of the upper end of the Cumberland Street sewer should be progressive with time, and the estimates include a sinking-fund provision for that purpose.

Seneca Street diversion.—The area now tributary to the Swan Street sewer is estimated to give rise to a future maximum sewage discharge of some 278 cubic feet per second, whereas the present interceptor capacity is limited to about 120 cubic feet per second. The present excess is taken care of by overflow weirs, and by the open gates through the weir at Hydraulic Street, permitting the discharge of sewage to the covered Hamburg Canal, which is in reality an extension of the Erie Canal with cross connections to the harbor. To care for the sewage in excess of the capacity of the present Swan Street sewer, it has been planned, among other relief measures, to divert from the upper end of the Swan Street district the subareas of Bailey Avenue, Babcock Street, Fillmore Avenue, and Emslie Street. This it is proposed to accomplish by tapping the existing sewer in Seneca Street in the vicinity of Maurice Street. The drainage from Fillmore Avenue and from Emslie Street has been cared for by laying out a sewer in Seneca Street which will run in reversal to the present line, bringing these two subdistricts back to junction with the Bailey Avenue and Babcock Street areas at Maurice Street. From this point a sewer has been run out Maurice and its prolongation, siphoning under the Buffalo River and reaching Ab-

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bott Road, where discharge can be secured to the South Buffalo interceptor at Abby Street.

In addition to these features it has been found from comparative estimates that ultimate economy will result if the diversion in Seneca Street between Emslie Street and Maurice be made large enough to receive in the future an increment of sewage from the Hamburg pumping station, and such allowance has been included in determining the sizes and in preparing the estimates.

This plan, it will be noted, utilizes the existing Seneca Street sewer between Bailey Avenue and Maurice Street, preserving the overflows at Bailey Avenue and at Babcock Street, though the weir for the latter will have to be lengthened and readjusted as to elevation. This sewer, though adequate for present needs, will have to be supplemented in capacity at some future date, either by enlargement or by duplicate construction, and sinking fund provision therefor has been included in the estimate. At Maurice Street this plan further calls for the construction of a weir to divert dry-weather flow to South Buffalo, thus permitting the utilization of the sewer north of this point to carry any excess escaping the Babcock Street overflow, and furnishing an outlet for storm flow from Fillmore Avenue and Emslie Street. From a construction viewpoint this scheme offers difficulties in the siphon at Buffalo River, but chiefly in the long railroad crossing near Fillmore Avenue.

Outlet.—The outlet, meaning thereby the discharge line from the treatment works to the harbor, has been shown in Tifft Street in shallow cut, requiring fill for cover. The fall has been kept light in order to conserve head, and the section itself is designed for economy of masonry. Pile foundation for this sewer has been included in the estimate.

The outlet proper has been shown in multiple. It consists of four lines of wood stave pipe laid in a dredged trench, aligned with piles and held in place with bagged or tremie deposited concrete. The discharges occur at 1,000, 1,200, and 1,500 feet from shore, representing approximately 12, 16, and 20 feet depths of water at mean stage. It is expected that two lines of pipe will be laid to the greatest distance, which is about 150 feet beyond the War Department pierhead line.

Tabular statements of the sewage quantities, sizes, and grades, are appended.

TABLE 121.—*South Buffalo sewage quantities, maximum rates of flow, 1950, Buffalo, N. Y.*

Subdistrict.	1950 population.	Area (acres).			Sewage flow, M. G. D.			Total sewage.		Cumulative sewage, C. F. S.
		Total.	Industrial.	Commercial.	Per capita, at 310 G. C. D.[1]	Infiltration at 1,850 and 1,000 G. A. D.[2]	Industrial, at 13,000 and 16,000 G. A. D.	M. G. D.	C. F. S.[3]	
Main line:										
Outside city	.....	800	.....	.....	.....	.....	.....	.....	7.5	.....
South Ogden Street	4,200	140	.....	.....	1.30	0.26	.....	1.56	2.4	9.9
Seneca Street	8,200	273	.....	.....	2.54	0.51	.....	3.05	4.7	14.6
Cazenovia branch, east	1,700	56	.....	.....	0.53	0.10	.....	0.63	1.0	15.6
South Park Avenue	4,000	138	.....	.....	1.24	0.26	.....	1.50	2.3	17.9
Cazenovia branch, west	23,700	892	.....	.....	See below.			.....	19.5	37.4
Boone Street	19,800	708	.....	.....	6.14	1.31	.....	7.45	11.5	48.9
Abby Street	4,000	392	338	.....	1.24	0.73	4.40	6.37	9.9	58.8
Seneca Street diversion	205,600	7,433	1,228	13	See below.			.....	158.1	216.9
Miscellaneous	14,400	868	451	.....	4.47	1.60	5.86	11.93	18.5	235.4
Total	285,600	11,700	2,017	13	.....	.....	.....	.....	.....	.....
Cazenovia branch, west:										
Outside city	.....	600	.....	.....	.....	.....	.....	.....	5.6	.....
Meriden Street	20,000	767	.....	.....	6.20	1.42	.....	7.62	11.8	17.4
Cumberland Street	3,700	125	.....	.....	1.15	0.23	.....	1.38	2.1	19.5
Seneca Street diversion:										
Outside city	.....	1,020	.....	.....	.....	.....	.....	.....	18.0	18.0
Bailey Avenue	54,000	1,944	319	.....	16.72	1.94	5.10	23.76	36.8	54.8
Babcock Street	10,500	508	98	.....	3.26	0.51	1.57	5.34	8.3	63.1
Additional	2,500	240	104	.....	0.78	0.24	1.66	2.68	4.2	158.1
Fillmore Avenue	73,000	1,364	371	.....	22.60	1.36	5.94	29.90	46.3	90.8
Emslie Street	37,700	516	57	.....	11.70	0.52	0.91	13.13	20.3	44.5
From Hamburg pumping station	27,900	941	279	13	See Ohio Basin Collector, Swan Street district.			.....	24.2	24.2

[1] G. C. D.—Gallons per capita daily. [2] G. A. D.—Gallons per acre daily. [3] C. F. S.—Cubic feet per second.

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TABLE 122.—*South Buffalo interceptor sizes, Buffalo, N. Y.*

Sewer.	Accumulated sewage, cubic feet per second (from Table 121).	Sewer.		
		Slope.	Size.	Velocity (feet per second.)
Main line:			*Ft. in.*	
Outside city	7.5			
South Ogden Street	9.9	0.0005	33	1.7
		.00045	36	1.7
Seneca Street	14.6	.00045	39	1.75
Cazenovia branch, east	15.6	.00045	39	
South Park Avenue	17.9	.00045	39	
Cazenovia branch, west	37.4	.0004	57	2.2
Boone Street	48.9	.0004	63	2.3
Abby Street	58.8	.0004	63	
Seneca street diversion	216.9	.00055	8 6	3.9
Miscellaneous	235.4			
Cazenovia branch, west:				
Outside city	5.6			
Meriden Street	17.4	.001	36	2.5
Cumberland Street	19.5	.001	39	2.7
Seneca street diversion:				
Outside city	18			
Bailey Avenue	54.8	.001	[1] 33	
Babcock Street	63.1	.0005	[1] 5 6	
Hamburg pumping station	23.2		[2]	
Emslie Street	43.5	.0009	51	3.1
Fillmore Avenue	89.8	.0005	6 3	3.0
Babcock Street	152.9	.0007	7 0	3.8
Additional	157.1			
Outlet	235	.0001	[3]	1.8

[1] Additional to existing sewers.
[2] 10 feet 6 inches by 14 feet.
[3] 30-inch force main.

In Table 122 it will be noted that the velocities in the upper portion of the South Buffalo interceptor are below those generally thought desirable. This is caused by the fact that the sewer elevations in this section establish the pump well elevation at the treatment works and are the result of an attempt to avoid intermediate booster pumps and to secure a balance between the cost of continuous pumping and that of occasional sewer cleaning. It is expected that sewers in which the velocity would be less than 2.5 feet per second will be constructed with particular attention to smoothness of surfaces.

The estimates which follow should be judged in total rather than in detail, for it is believed that the differences and excesses unavoidably present through lack of information will largely average out. The costs are given in such form as to enable the determination of the influences of any particular portion upon the cost as a whole.

SWAN STREET DISTRICT.

This district contains the most densely populated areas, as well as all the commercial section; it also includes the older portions of the city, and from an interception viewpoint offers the greatest obstacles, both to the collection of dry-weather sewage and to the handling of storm water.

A glance at the sewerage map in the vicinity of Swan Street, between Main Street and Fillmore Avenue, reveals the complications existing and required, a condition rendered more confusing by uncertainty as to elevations in some of the older sewers, though the city records for more recent construction are complete.

Extension to Squaw Island.—The existing Swan Street sewer discharges into the Niagara River near Albany Street, being joined by the smaller Albany Street sewer prior to crossing the Erie Canal.

The plan outlined upon the sewerage map calls for the extension of this sewer along the Bird Island Pier. It is quite probable that in the near future the city will rebuild and widen the existing pier, in which event the sewer extension could be included at relatively small cost. The estimate submitted disregards this probability.

While the construction of this extension is not particularly difficult, it is not easy to determine the minimum expenditure that will satisfy the requirements. The present pier is built of rough riprap laid without bond, and is satisfactory as a foundation in uncertain degree. At points the present wall appears quite solid, apparently being well founded upon nonsettling bottom. At other points, and notably toward Squaw Island, the pier is probably unsatisfactory. The subfoundation is rock at the southern end, but this shelves off toward the north. Borings, and a study of the history of this structure, are needed prior to outlining any definite plan of operations. Fortunately, however, unless constructed as a part of a permanent pier development, it is not necessary for any sewer extension to carry great loads. Moreover, as the conduit need not be under earth cover, a moderate settlement of the structure in any part will not be prejudicial to the operation of the whole, and can be easily remedied.

The plan upon which the estimate has been based assumes either that independent pile foundation will be provided or that the present wall can be utilized for foundation if restrained against sliding and if supplemented by occasional piles. Restraining walls could be provided by steel sheet piling backed on the canal side with concrete.

The structure itself has been designed as a twin concrete conduit with slab roof and with invert above river level. The slab roof is not essential the full length of the extension, but has been included as desirable if the pier is to be used.

Relief measures.—The measures suggested for the relief of the overloaded Swan Street sewer have been outlined in the description of South Buffalo sewerage. This sewer is 8 feet in diameter, built of brick and stone masonry on a 0.000215 grade. With N=0.015, the theoretical capacity full is 112 cubic feet per sec-

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TABLE 123.—*South Buffalo—Estimates of interceptor construction costs.*

	From—	To—	Length.	Size.	Depth, excavation.	Cost per lineal foot.	Cost.
1. South Buffalo interceptor:			*Feet.*	*Feet.*	*Feet.*		
a. Main line	Mineral Springs Road	Seneca Street	3,100	2¾	12	$6.15	$19,065
			3,000	3	12	7.00	21,000
b. Main line	Seneca Street	Abby Street and Abbott Road.	1,200	3½	16.5	8.35	10,020
c. Main line			4,220	4¾	16.3	14.40	60,768
d. Main line			1,100	5½	18.6	17.10	18,810
e. Main line	Abby Street and Abbott Road	Tifft and Abby Streets	4,700	8½	21	33.50	157,450
f. Outlet [1]	Tifft and Abby Streets	Harbor	5,200	10½ by 14	13	56.80	295,360
2. Buffalo Creek branch			1,880	1	12	3.00	5,640
3. Cazenovia Branch, east:							
a	South Park Avenue	Hammerschmidt	1,350	1	10	3.30	4,455
b	Rebuilding Ryan and Geary Streets		2,400	1	8	2.00	4,800
4. Cazenovia branch, west:							
a	South Park Avenue	Mumford	1,840	3½	14	10.55	19,412
b	Meriden Street connection		75	3	12	7.40	555
c. Sinking fund	Extending Meriden Street connection		312	2¾	12		1,550
5. Seneca Street diversion:							
a	Emslie Street	Fillmore Avenue	1,700	4½	10.7	17.00	28,900
b	Fillmore Avenue	Maurice Street	2,350	6½	16	24.00	56,400
c	Seneca and Maurice Streets	Tift and Abby Streets	4,800	7	17.3	31.65	151,920
d	Babcock Street connection over Elk		600	1	10	3.95	2,370
e. Sinking fund	Hamburg pumping station, force main		1,800				25,000
f. Sinking fund	Enlarging between Bailey Avenue and Maurice Street.		3,750				30,000
6. Connections and reconstruction							15,000
Total			45,377				929,650

[1] Multiple outlet in harbor, 4 lines. Included with treatment works.

ond, though it is doubtful if 0.015 be the correct coefficient. At the lower end is exhibited a decided increase of slope in the hydraulic surface, resulting in a depth decrease of from 5.4 feet at Georgia Street to 3.6 feet just south of Albany Street, a slope for which Mr. George H. Norton, city engineer, has established analytical values and which offers a certain surplus capacity. The trouble, however, occurs in the upper reaches, both by means of insufficient capacity and through inability to use the full available capacity because of backwater conditions in certain vaguely defined areas. It would be quite possible to cut-off these low areas to an outlet through a pumping station, but the resulting increase in capacity would still be insufficient. Table 124 embodies a tabular statement of conditions as estimated to obtain in 1914.

TABLE 124.—*Swan Street sewer—Maximum sewage flow, 1914, Buffalo, N. Y.*

Subdistrict.	Population.	Area (acres).			Sewage flow, M. G. D.				Sewage flow.			Sewer capacity, C. F. S.	Deficiency C. F. S.
		Total.	Industrial.	Commercial.	Per capita at 330 G. C. D.	Ground water at 1,000 G. A. D.	Industrial at 11,000 G. A. D.	Commercial at 30,000 G. A. D.	M. G. D.	C. F. S.	Accumulated C. F. S.		
OUTSIDE CITY.													
Bailey Avenue	23,284	1,944	319	.....	7.68	1.94	3.51	.....	13.13	20.3	20.3	.....	.....
Babcock Street	5,356	508	98	.....	1.76	.51	1.08	.....	3.35	5.2	25.5	.....	.....
Do	1,925	240	104	.....	.64	.24	1.14	.....	2.02	3.1	28.6	.....	.....
Fillmore Avenue	66,362	1,364	371	.....	21.90	1.36	4.08	.....	27.34	42.3	70.9	.....	.....
Emslie Street	35,210	516	57	.....	11.62	.52	.63	.....	12.77	19.8	90.7	.....	.....
Smith Street	3,800	260	79	.....	1.25	.26	.87	.....	2.38	3.7	(1)	.....	.....
Hamburg pump	14,360	556	142	13	4.74	.56	1.56	0.39	7.25	11.2	101.9	.....	.....
Ohio Basin	4,600	125	58	.....	1.52	.13	.64	.....	2.29	3.5	(1)	.....	.....
Spring	21,460	324	.....	.....	7.08	.32	.....	.....	7.40	11.5	113.4	.....	.....
Michigan Street	13,560	251	29	146	4.48	.25	.32	4.38	9.43	14.6	128.0	120	8.4
Genesee Street	38,190	763	.....	190	12.60	.76	.....	5.70	19.06	29.5	157.5	120	37.5
Canal collector	13,654	319	123	28	4.50	.32	1.35	.84	7.01	10.9	(1)	.....	.....
Carolina Street	18,860	383	23	118	6.22	.38	.25	3.54	10.39	16.1	173.6	[3] 120	53.6
Hudson Street	11,690	242	.....	.....	3.86	.24	.....	.....	4.10	6.3	179.9	[3] 120	59.9
Porter Avenue	2,230	113	.....	.....	.74	.11	.....	.....	.85	1.3	[2] 181.2	[3] 120	61.2
Total	274,541	7,908	1,403	495	90.59	7.90	15.43	14.85	128.77	199.3	.....	.....	.....

[1] Not now tributary to Swan Street sewer.
[2] Cf. Table 119, which shows an average between extreme winter flow and summer maximum.
[3] Capacity noted is nominal and is subject to a small variable increase owing to the drop in the hydraulic slope.

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Aside from all estimates of present and of future sewage flows, an interceptor which provides capacity to the extent of 283 gallons per capita is inadequate for maximum rates when the average water consumption is 324 gallons per capita. When compared with future requirements the discrepancy becomes more pronounced.

It will be observed that the foregoing statement regards the existing throttling section of the trunk sewer in Seneca Street between Hamburg Street and Hydraulic Street as enlarged, a contract to this end being in process of consummation at the time of writing. This reconstruction harmonizes with the present plan, in that it will be needed for storm water overflow.

To repeat, the relief suggested involves diversion of the upper drainage areas from Bailey Avenue to and inclusive of Emslie Street. With this sewage deducted, the existing interceptor can carry the balance for some years, probably until 1925, at which time if the surplus capacity at the lower end does not prove sufficient, further relief will be required either by duplicate interceptor construction to Carolina Street, or else, and more economically, by extending a force main from the Hamburg Street pumping station through the existing sewer to the proposed diversion sewer at Emslie Street. The estimate includes sinking fund provision for this latter item.

An element of this project which detracts somewhat from its merits is the occurrence of low velocities in the upper end, as a result of any considerable diversion of sewage, and it might be desirable to consider the possibility of maintaining depth of flow by permitting as much as possible of the upper area flow to run to Squaw Island. The estimate includes a small allowance for pointing up the interior of the trunk sewer and for filling sumps occasioned by settlement.

The diversion of upper area sewage from Swan Street will be conducted in such fashion as to utilize the existing drain above Hamburg Street, hence it will be necessary to construct a bulkhead at Hamburg Street to force the storm water either through the Hamburg Street overflow or else back to the Millrace sewer at Hydraulic Street. In addition it will be necessary to seal all connections between the intercepter and the Hamburg Canal save as they exist at such elevation as to be utilized only as relief overflows.

Ohio Basin collector.—Much of the marginal territory below Elk Street now drains directly or indirectly to Buffalo River. Some of the area it is proposed to serve by means of a small lateral which will intercept four sewers now discharging into the Ohio Basin, and which, in combination with the diversion from Smith Street, will extend up Hamburg Street to the existing pumping station. At the pumps it can be lifted to Swan Street, or in the future to South Buffalo. Up to the pumping station itself the discharge can be secured by gravity, but a small automatic pump unit has been shown on the plan as offering a saving in deep-cut construction; it is not essential.

River front collector.—Numerous small sewers discharging to the river from streets lying in the interval between Michigan and Evans Streets it is proposed to gather into an interceptor which, running along Ohio, Prime and Water Streets, would center to an automatic pump at Prime and Hanover Streets, thence lifting to an existing dry weather collector laid in a wall of the old Hamburg Canal. To accomplish some of the results here included, the bureau of engineering has contemplated a somewhat different alignment with the same point of discharge, but with the advantage that pumping would not be necessary. The difference between the two projects is probably one of scope, for the fall available from sewer outlets to the Hamburg collector is 5.45 feet as a maximum and 3.5 as a minimum, whereas the least distance from any outlet to the collector is about 1,200 feet.

Canal collector.—An additional marginal collector has been planned to follow the east bank of the Erie Canal from Evans Street to Genesee Street, with a pump lift at this point to a discharge line to the main interceptor. This line would receive sewage from four or five small laterals which now empty into the Canal.

Other streets north of Genesee to Porter Avenue are also provided with local sewers, which receive any overflow from Swan Street sewer, together with some local sewage, though, judging by the development of this territory, this sewage is small in amount. The drainage from this area has been omitted from consideration, though should at any time its interception be deemed desirable, it will be found most economic to relay and reverse sewers for sanitary drainage, or else to install an automatic pump at each street.

In connection with any work tending toward the improvement of the canal, the city could well devote some attention to several private drains now connected thereto, and particularly in the stretch between Main and Genesee Streets.

Hydraulic Street district.—There is a small low-lying area, bounded by Seneca, Hamburg, and Roseville Streets, which drains to the Millrace sewer and to a small sanitary interceptor extension from the Hamburg pumping station.

Sewer records for this area are generally meager or conflicting. On the ground the situation is also puzzling, so that it is impracticable to offer profiles or any very definite procedure. A study of what data is available indicates the following as a mode of attack:

(1) To reconstruct and lower the Larkin Street sewer from Seneca to Roseville, connecting to the existing dry weather collector at the latter street.

(2) At Seneca Street to divert the existing 24-inch sewer west of Larkin Street into the rebuilt Larkin

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Street sewer; and further to reconstruct and reverse the existing Seneca Street sewer between Larkin and Van Rensselaer Streets.

(3) In Carroll Street to reconstruct the existing sewer, making Van Rensselaer Street the summit, and running thence west and east, respectively, to Larkin Street and to the existing collector in Hydraulic Street.

(4) At Exchange and Hydraulic Streets to intercept the Exchange Street flow east of Hydraulic Street, and, if need be, reversing the portion between Hydraulic Street and the Millrace sewer.

This program is not as formidable as it sounds, but does involve detailed surveys and careful planning. The total length of the construction described is 2,800 feet, all of small size.

The sewer in Carroll Street east from the Millrace sewer appears to be abandoned, but if needed could be connected to the collector at Hydraulic Street.

Storm-water diversion.—It is essential that the connection between lateral and interceptor be such as to protect the latter from any great burden of storm water, and while no attempt has been made to review the matter of storm drainage by itself, there are several locations where particular precautions are needed.

At Pine Street it is suggested that the storm flow be diverted from the interceptor by means of a short connection to Chicago Street.

At Oak and Seneca Streets, a diversion to either Michigan Street or to an existing storm sewer in Seneca at Ellicott is feasible.

At Jefferson and Seneca Streets it will be preferable to leave the storm drainage undisturbed, intercepting and diverting the sanitary flow in a small sewer which would connect to the interceptor west of the proposed bulkhead.

At several cross streets north of Genesee Street the existing connection between lateral and interceptor is of a type which permits local flooding and overloading of the interceptor in time of storm. This condition can be met by the construction indicated on plate 37.

Genessee Street sewer.—The 6½-foot trunk sewer in Genesee Street has a 0.0064 grade prior to entry to the Swan Street sewer. This subtrunk, in addition to carrying considerable storm drainage, is used as the point of disposal for snow removed from the streets. This latter fact in particular, coupled with the checking of velocity at the junction, is responsible for a considerable deposit of grit in the trunk sewer. To remedy this condition, the estimate has been made to include provision for a local grit chamber. The location of the junction is favorable to such construction which could well be combined with the diversion required at this point.

TABLE 125.—*Swan Street district sewage quantities—Maximum rates of flow, 1950, Buffalo, N. Y.*

Subdistrict.	1950 population.	Area (acres).			Sewage flow, M. G. D.				Total sewage.		
		Total.	Industrial.	Commercial.	Per capita at 310 G. C. D.	Infiltration at 1,000 and 1,850 G. A.D.	Industrial at 16,000 G. A. D.	Commercial at 60,000 G. A. D.	M. G. D.	C. F. S.	Cumulative sewage C. F. S.
Main interceptor:											
Hamburg pumping station	17,300	556	142	13	5.37	1.03	2.27	0.78	9.45	14.6	.....
Ohio Basin	10,600	385	137	.....	See below.				.....	9.6	[1] 24.2
Spring Street	23,300	324	.....	.....	7.23	.32	.....	.....	7.55	11.7	.....
Michigan Street	15,500	251	29	146	4.80	.25	.46	8.76	14.27	22.2	33.9
Genesee Street	45,000	763	.....	190	13.94	.76	.....	11.40	26.10	40.4	74.3
Canal	13,700	319	123	28	4.25	.32	1.97	1.68	8.22	[2] 12.7	87.0
Carolina Street	23,300	383	23	118	7.23	.38	.37	7.08	15.06	23.3	110.3
Hudson Street	14,600	242	.....	.....	4.53	.24	.....	.....	4.77	7.4	117.7
Porter Avenue	3,100	113	.....	.....	.96	.11	.....	.....	1.07	1.7	119.4
Albany Street	40,000	896	49	.....	12.40	.90	.64	.....	13.94	21.6	141.0
Total	178,500	3,291	224	482	.....	.....	.....	.....	.....	.....	141.0
Ohio Basin:											
Smith Street	4,600	260	79	.....	1.43	.48	1.27	.....	3.18	4.9	.....
Hamburg Street	.....	42	42	.....	.....	.08	.67	.....	.75	1.2	6.1
Basin sewers	3,140	83	16	.....	.97	.15	.26	.....	1.38	2.1	8.2
Miscellaneous	2,860	.....	.....	.....	.89	.....	.....	.....	.89	1.4	9.6
River front.[3]											
Canal collector.[3]											

[1] Provision made for future diversion to South Buffalo.
[2] Includes total area tributary to canal; lateral interceptors for draining all this not included. See text.
[3] No subdivision made.

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The sewerage work suggested for the Swan Street district, representing as it does measures intended to relieve the trunk sewer and to gather up small marginal drainage, there are expressed in Table 126 only the characteristics of minor new collectors, the main interceptor remaining unchanged.

TABLE 126.—*Swan Street district interceptor sizes, Buffalo, N. Y.*

Sewer.	Sewage, cubic feet per second (from Table 125).		Sewer.		
	Total.	Accumulated.	Slope.	Size.	Velocity (feet per second).
Ohio Basin collector:				*Inches.*	
Smith Street	4.9	4.9	0.0016	22	2.3
Hamburg Street	1.2	6.1	.0016	22	2.3
Basin sewers	2.1	2.1	.005	12	2.5
Miscellaneous	1.4	3.5	.003	15	2.3
	.....	9.6	.0025	24	3.0
River front collector:					
Michigan to Prime	.....	2	.005	12	2.5
Evans to Prime	.....	2	.005	12	2.5
Prime to Hamburg	.....	8	.003	15	2.3
Canal collector: Evans to Genesee	.....	2	.005	12	2.5

BIRD AVENUE DISTRICT.

The Bird Avenue trunk sewer was formerly connected to the Swan Street sewer outlet by means of a former sewer and to seep through the canal wall. According to the opinion of the city engineer, the number and length of breaks in the original sewer are such as to render new construction advisable. An automatic pump will be needed to attain the level of the Bird Avenue sewer.

sewer in the east canal towpath from Bird Avenue to Albany Street. Broken in several stretches at the time of the enlargement of the Erie Canal, this connection has been sealed, and the overflow into the canal at Bird Avenue utilized for the dry weather discharge.

Bird Avenue extension.—To bring the sewage of this district to treatment works on Squaw Island requires extension of the existing sewer in the form of an inverted siphon crossing of the canal. Also in order to utilize to the fullest extent the natural high sewer level, a short piece of reconstruction will be advisable as a feature eliminating the question of pumping. Inasmuch as the treatment contemplated involves the use of a grit chamber, it appears preferable to construct such on the mainland prior to the crossing, in order to protect the siphon. The space available is sufficient for this, though it will be necessary to roof over the chamber.

The siphon itself has been planned as a triple concrete box structure with sufficient difference of head between the ends to maintain proper velocity. Construction will have to be conducted in coffer, as this portion of the canal is not drained during the winter.

Canal collectors.—To replace the broken connection between Albany Street and Bird Avenue it will be necessary to build a small interceptor to receive marginal drainage which now appears to empty into the

TABLE 127.—*Swan Street district—Estimates of interceptor construction costs.*

Sewer.	From—	To—	Length.	Size.	Depth, excavation.	Cost per lineal foot.	Cost.
			Feet.	*Feet.*	*Feet.*		
7. Swan Street extension	Albany Street	Squaw Island	3,000	2–5 x 9	.....	$90.00	$270,000
8. Ohio Basin collector:							
a. Smith Street branch	Smith Street	Hamburg Street	3,900	1.83	12.5	5.35	20,865
b. Louisiana Street	Republic Street	Mackinaw Street	1,600	1	11.5	6.00	9,600
c. Mackinaw Street	Wabash Street	Louisiana Street					
d. Mackinaw Street	Louisiana Street	Hamburg Street	1,650	1.25	17	5.80	9,570
e. Hamburg Street	Mackinaw Street	Pumping Station	2,100	2	7	5.20	10,920
f. Automatic pump	.....	.....	.....	.....	.....	.....	4,000
9. River front collector:							
a. Ohio and Water	Michigan Street	Evans Street	4,250	1	16	7.40	31,450
b. Hanover	Prime Street	Main Street	500	1	13	5.60	2,800
c. Scott Street	Main Street	Burwell Place	360	1.25	15	6.70	2,412
d. Commercial Street branch	.....	.....	575	1	8	3.65	2,100
e. Automatic pump	.....	.....	.....	.....	.....	.....	3,000
10. Canal collector:							
a. Canal bank and Genessee	Evans Street	Genessee and Terrace	3,000	1 1.25	6	2.40	7,200
b. Automatic pump	.....	.....	.....	.....	.....	.....	2,500
11. Hydraulic Street	District reconstruction	.....	2,800	1	±13	3.80	10,640
12. Storm sewers:							
a. Swan Street	Pine Street	Chicago Street	130	2.25	11	8.50	1,105
b. Swan Street	Oak Street	Michigan Street	870	4.25	12.5	13.85	12,050
c. Jefferson Street [1]	.....	.....	320	1	2	5.60	1,792
d. Modifying 10 existing connections	.....	.....	.....	.....	.....	.....	7,500
13. Genessee Street grit chamber	.....	.....	.....	.....	.....	.....	7,500
Total	.....	.....	25,055	.....	.....	.....	417,004

[1] See text.

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The canal strip north of Bird Avenue is also the source of some drainage into the canal. To collect this an interceptor in the east towpath has been planned to run from Bird Avenue to Hertel Avenue.

TABLE 128.—*Bird Avenue district sewage quantities—Maximum rates of flow, 1950, Buffalo, N. Y.*

Subdistrict.	1950 population.	Area (acres).			Sewage flow, M. G. D.				Total sewage.		Cumulative sewage, C. F. S.
		Total.	Industrial.	Commercial.	Per capita, at 310 G. C. D.	Infiltration, at 1,000 G. A. D.	Industrial, at 13,000 G. A. D.	Commercial, at 60,000 G. A. D.	M. G. D.	C. F. S.	
Bird Avenue trunk	194,000	6,372	469	73	60.20	6.37	6.10	4.38	77.05	119.3	.....
Outside city	.....	1,320	.....	.....	.....	.....	.....	.....	.....	12.4	131.7
Canal collector, south:											
West Ferry Street	[1] 850	17	6	.....	.26	.02	.08	.....	.36	.6	.6
Breckenridge Street	5,750	115	11	.....	1.78	.12	.14	.....	2.04	3.2	3.8
Brace Street	2,850	57	6	.....	.88	.06	.08	.....	1.02	1.6	5.4
West Delavan Avenue	900	18	6	.....	.28	.02	.08	.....	.38	.6	6
Potomac Avenue	2,800	56	6	.....	.87	.06	.08	.....	1.01	1.5	7.5
Canal collector, north:											
Hertel Avenue	[2] 675	15	.....	.....	.21	.02	.....	.....	.23	.4	.4
Farmer Street	1,260	28	.....	.....	.39	.03	.....	.....	.42	.7	1.1
Austin Street	1,850	41	.....	.....	.57	.04	.....	.....	.61	.9	2
Hamilton Street	1,125	25	20	.....	.35	.03	[3] .26	.....	.64	1	3
Parrish Street	2,600	58	.....	.....	.80	.06	.....	.....	.86	1.3	4.3
Wayne Street	495	11	.....	.....	.15	.01	.....	.....	.16	.3	4.6
Niagara Street	945	21	.....	.....	.29	.02	.....	.....	.31	.5	5.1
Total	216,100	8,154	524	73	.....	.....	.....	.....	.....	.....	144.3

[1] Population estimated at density of 50 per acre. [2] Population estimated at density of 45 per acre. [3] Lump allowance for whole district.

TABLE 129.—*Bird Avenue district—Interceptor sizes, Buffalo, N. Y.*

Sewer.	Accumulated sewage, cubic feet per second (from Table 128).	Sewer.		
		Size.	Slope.	Velocity (feet per second).
		Ft. in.		
Bird Avenue trunk	131.7	8	0.00025	2.5
Canal collector, south:				
West Ferry Street	.6	12	.005	2.5
Breckenridge Street	3.8	18	.003	2.7
Brace Street	5.4	22	.0025	2.8
West Delavan Avenue	6.	.....	.....	.....
Potomac Avenue	7.5	24	.002	2.7
Canal collector, north:				
Hertel Avenue	.4	12	.005	2.5
Farmer Street	1.1	.....	.....	.....
Austin Street	2.	15	.0035	2.5
Hamilton Street	3.	18	.0025	2.5
Parrish Street	4.3	22	.002	2.5
Wayne Street	4.6	.....	.....	.....
Tonawanda Street	5.1	.....	.....	.....

HERTEL AVENUE DISTRICT.

Project VI, as previously described, included an interceptor in or near Niagara Street to convey the sewage of the Hertel Avenue area to Squaw Island. This plan would involve the construction of 7,100 feet of 6-foot 9-inch sewer at a cost of $260,000, and it has seemed preferable to revise this feature of the project in favor of local treatment. To collect marginal drainage it will be necessary to build a small sewer in the canal towpath from Hertel Avenue to Bird Avenue, with outlet at the latter point. The cost of such a line will approximate $44,093 (see Table 130), leaving part of the difference as applicable to the increased cost of separate treatment.

Disposal area for Hertel Avenue sewage is available in the vicinity of the existing outlet, thus necessitating but short extensions of present sewerage.

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TABLE 130.—*Bird Avenue district—Estimates of interceptor construction costs, Buffalo, N. Y.*

Sewer.	From—	To—	Length.	Size.	Depth excavation.	Cost per lineal feet.	Cost.
			Feet.	*Feet.*	*Feet.*		
14. Bird Avenue siphon	Mainland	Squaw Island	600	4 by 15		$195.00	$117,000
15. Canal collector, south:							
Towpath	West Ferry	Breckenridge	800	1	4	1.75	1,400
	Breckenridge	Brace	1,350	1.5	7.5	4.45	6,008
	Brace	Potomac	1,230	1.83	11	6.65	8,180
	Potomac	Bird	700	2	14	8.80	6,160
Automatic pump							3,000
16. Canal collector, north:							
Niagara	Tonawanda	Canal	1,780	1	10	4.60	8,188
Towpath	Hertel	Austin					
	Austin	Hamilton	720	1.25	3	1.65	1,188
	Hamilton	Parrish	1,600	1.50	7	5.20	8,320
	Parrish	Bird Avenue	2,340	1.83	8	9.55	22,347
Two automatic pumps							4,050
		Total	11,120				185,841

It is, however, feasible to effect some economy in the present mode of collection by intercepting the sanitary flow of the Ontario Street subtrunk at a high level and carrying the same over Tonawanda Street 1,500 feet to the Hertel Avenue sewer. The effect of this diversion will be to bring the Ontario Street drainage in at a higher level than could otherwise be secured. The Ontario Street sewer below Tonawanda Street will in such case be used as a storm-water drain and in addition will receive sanitary wastes from that portion of the district below the point of diversion; this latter increment will be intercepted at Cornelius Creek.

The existing sewer in Hertel Avenue from Tonawanda Street to Niagara Street is a 57-inch sewer and is really a sanitary extension of the combined sewer which as recently extended stops at Tonawanda Street and Cornelius Creek. In its present form the sewer is large enough (capacity 70 cubic feet per second) to carry the present-day flow of 38 cubic feet per second, but in 1935 will have to be supplemented by the construction of 2,100 feet of 42-inch sewer to successfully deliver the expected 1950 sanitary flow of 95 cubic feet per second. This enlargement of capacity is not the direct result of diverting the Ontario Street flow, though were that not done the duplication could be deferred somewhat. However, even with this disadvantage the scheme described is the more economic, and has been embodied in the plans for this district, though should first cost be the determinent the construction can be deferred to a more opportune time.

TABLE 131.—*Hertel Avenue district sewage quantities—Maximum rates of flow, 1950, Buffalo, N. Y.*

Subdistrict.	1950 population.	Area (acres).			Sewage flow, M. G. D.			Total sewage.		Cumulative sewage C. F. S.
		Total.	Industrial.	Commercial.	Per capita, at 310 G. C. D.	Infiltration, at 1,000 G. A. D.	Industrial, at 13,000 G. A. D.	M. G. D.	C. F. S.	
Hertel Avenue trunk:										
Total	119,900	4,581	1,139		37.20	4.58	14.80	56.58	87.6	
Outside city		780							7.3	94.9
Total	119,900	5,361	1,139							94.9
Ontario Street:										
Diversion	[1] 13,650	455	54		4.23	.46	.70	5.39	8.4	
Outside city		128							1.2	9.6
Ontario Street: South of Tonawanda	[1] 3,720	124			1.15	.12		1.27	2	

[1] On basis of density of 30 per acre.

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TABLE 132.—*Hertel Avenue district interceptor sizes, Buffalo, N. Y.*

Sewer.	Accumulated sewage, cubic feet per second (from Table 131).	Sewer.		
		Size.	Slope.	Velocity (feet per second).
		Ft. in.		
Ontario Street diversion	9.6	30	0.001	2.3
Hertel Avenue sewer, including Ontario	94.9	4 9	.0013	[1] 4
		3 6	.0013	[2] 3.2

[1] Existing sewer.
[2] Future additional sewer or existing 4 feet 9 inches may be replaced by a 5½-foo sewer on the same grade.

TABLE 133.—*Hertel Avenue district—Estimates of interceptor construction costs, Buffalo, N. Y.*

Sewer.	From—	To—	Length.	Size.	Depth excavation.	Cost per lineal foot.	Cost.
			Feet.	*Feet.*	*Feet.*		
17. Ontario Street diversion: Tonawanda Street.	Ontario Street.	Hertel Avenue.	1,500	2½	18	$11.20	$16,800
18. Niagara Street	Existing sewer.	Pump	250	1½	15±	6.00	1,500
19. Enlarging Hertel Avenue sewer—sinking fund.	.....	.....	2,100	.....	.....	.....	10,900
Total	.....	.....	3,850	.....	.....	.....	29,200

SUMMARY.

To present a consolidation of the estimates of cost, there is appended Table 134, which carries forward the totals of sewer construction costs required in the different drainage districts.

TABLE 134.—*Interceptor costs—Summary of total, project VI, Buffalo, N. Y.*

Sewers.	Length.	Cost.
South Buffalo interceptors (Table No. 123)	45,377	$929,425.00
Swan Street interceptors (Table No. 127)	25,055	417,004.00
Bird Avenue interceptors (Table No. 130)	11,120	185,841.00
Hertel Avenue interceptors (Table No. 133)	3,850	29,200.00
Total	85,402	1,561,470.00
Average cost per foot	.....	18.28
Average cost per lineal foot per foot diameter, with siphon, pier extension, sinking fund, and special features deducted	.....	3.72

The unit cost in Table 134 of $3.72 per lineal foot per foot of diameter is comparable with a similar unit price of $2.39 derived from nine city contracts executed in the period 1908–1911 and covering the construction of 25,600 lineal feet of sewer varying in diameter from 8 inches to 51 inches, and aggregating in cost $142,700. With pipe sewers practically eliminated, this price reduces to $2.10 per lineal foot per foot of diameter. This statement is introduced as a basis for a rough determination of the reasonableness of the sewer costs included in this report.

It will be observed that the different items included in the estimates fall into two classes—

(*a*) Those consisting principally of large sewers carrying or diverting considerable quantities of sewage.

(*b*) Smaller sewers designed to pick up residual drainage which, though tangible in the aggregate, is individually small and for its collection requires considerable outlay per unit of flow.

This subdivision leads to a possible economy in the first cost of interception by deferring the construction of minor collectors until the completion of the major

TABLE 135.—*Average sewage flow, 1930, Buffalo, N. Y.*

Drainage district.	Population.[1]	Area (acres).[2]			Sewage flow, M. G. D.[3]				Total M. G. D.
		Total.	Industrial.	Commercial.	Per capita, at 150 G. C. D.	Infiltration, at 850 and 1,400 G. A. D.	Industrial, at 6,500 and 10,000 G. A. D.	Commercial, at 30,000 G. A. D.	
South Buffalo	197,040	2,652	789	.....	29.6	2.25	5.13	.....	66.58
		4,787	949	.....	.....	6.70	9.49	.....	
Outside city	.....	(3,320)	.....	.....	(13.41)	.....	.....	.....	
Swan Street	199,100	3,201	503	495	29.9	2.80	5.03	14.85	53.90
		940	.....	.....	.....	1.32	.....	.....	
Bird Avenue	140,090	6,834	524	73	21.2	5.81	3.41	2.19	37.94
Outside city	.....	(1,320)	.....	.....	(5.33)	.....	.....	.....	
Hertel Avenue	66,940	458	1,139	.....	10.0	3.89	7.40	.....	24.46
Outside city	.....	(780)	.....	.....	(3.16)	.....	.....	.....	
Total	603,170	23,086	3,904	568	90.5	22.77	30.46	17.04	182.88

[1] The result of distributing the total shown in Table 103. In this case the Swan Street district includes the Hamburg pumping station area, which for future collecto design was included with South Buffalo.
[2] Taken from Tables 121, 125, 128, and 131 and preserving the differences there recorded from the gross areas in Table 104. These differences arise from planimetering errors and from the omission of certain areas in the detailed subdivisions.
[3] A 1930 interpolation of average flow units as derived from Table 120. "Outside city" areas accepted in full as determined for the future with average flow 67 per cent of the maximum rate.

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lines. Arbitrary determination of the line of demarcation indicates that the first cost can in this way (and by the elimination of sinking funds) be decreased some $225,000 and still permit the collection of over 97 per cent of the sewage as expected in 1950, and a consequently greater proportion of present-day amounts.

TREATMENT OF SEWAGE.

Following the conclusions of the general report, studies have been made to the end of applying the clarification processes there described to the particular conditions obtaining in Buffalo.

Treatment designs have been based upon the sewage flow as estimated for 1930, in order that in addition to providing treatment works in reasonable anticipation of future needs, there will be included a period of inaction during which legislation can be initiated, financial measures considered, and experiments conducted.

Table 135 presents a statement of average sewage flow estimated upon the basis of previous average units as applicable in 1930.

To further exhibit the distribution of the sewage allowance there is offered Table 136.

TABLE 136.—*Average sewage quantities, 1930—Subdivision—Per capita—Buffalo, N. Y.*

District.	Gallons per capita daily					
	Per capita allowance.	Infiltration.	Industrial.	Commercial.	Outside city.	Total.
South Buffalo.....	150	45	74	.....	68	337
Swan Street.....	150	21	25	75	.....	271
Bird Avenue.....	150	41	24	16	38	269
Hertel Avenue.....	150	58	111	.....	47	366

SEDIMENTATION.

The plans prepared for the different works, and here presented in accompanying plates, are similar in involving several steps in the complete process, as follows:

(*a*) Short time and high velocity subsidence, together with coarse screening to remove bulky trash from the sewage, and to take out heavy inorganic matter in suspension.

(*b*) Pumping.

(*c*) Disinfection with a solution of bleaching powder.

(*d*) Subsidence for a nominal period of 2.4 hours in Imhoff tanks.

Grit chambers.—The detritus tanks, as designed, have not been shown in any detail upon the plates, being patterned after more or less standardized types. In brief, they consist of a widening of the sewer sections and of subdivision into multiple channels. These channels are designed with cross sections and length such as to give a 60-second detention with a velocity of 1 foot per second, and also of such capacity as to provide sand storage for a three-day period at the rate of 10 cubic feet per million gallons. The channels have been planned to be five in number, four in effective use, and the fifth in process of cleaning or in reserve.

For cleaning various devices have been adopted. At the South Buffalo plant hand cleaning has been included, with transportation of grit in small cars running upon track laid in the floor and with elevation of the material by a derrick located at the ground surface. At Squaw Island provision has been made for cleaning by a centrifugal sand pump drawing through a flexible suction line fitted with a cutter head and discharging to a draining bed which will drain to the pump well. In either case it is expected that the sand will be used for replenishing sludge beds and for filling.

At the outlet end of the grit chamber the full section width has been maintained, but with the partition walls omitted to form a pump well which, for the maximum 1950 flow, will have capacity for less than one minute's storage, and though with the surplus interceptor capacity the effective storage period is increased, it will be necessary to follow the fluctuations of flow quite closely in the operation of the pumps. With long sewer lines such as are present in Buffalo, this fluctuation is quite gradual, and with constant attendance at the pump house can be readily met.

Screens of the bar type have been placed in advance of the grit chambers. The bars are spaced 1½ inches and set on a 1 on 2 slope. To prevent flooding there is provided a high level by-pass weir which will come into operation should the screens become clogged. Cleaning of screens will be accomplished with hand rakes, the screenings being incinerated.

Pumps.—The pump units are horizontal centrifugal pumps of ratings to meet 1930 flows, but with ability to deliver to the maximum interceptor capacities as representative of storm-flow conditions. Motor drive has been included for the Hertel Avenue plant, with steam in the case of the Swan Street and South Buffalo works. The Bird Avenue trunk sewer will discharge by gravity, except upon rare occasions, when a minimum flow in the sewer synchronizes with flood conditions in the river, at which time the sewage will back up sufficiently to obtain the necessary head, but not sufficiently to affect laterals.

The Swan Street pumping lift is so low that investigation has been made as to the possibility of backing up the flow to the point where pumping would be obviated except in time of flood. This is practicable, but owing to the flat grade of the sewer, there would be entailed a backing up to the vicinity of Carolina Street, with a consequent lowering of velocities

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for certain periods of flow to the point where deposition would occur.

Steam equipment has been provided at Squaw Island and at South Buffalo, primarily to offer a convenient method for the disposal of treatment works residual products, whether they be sludge or screenings. This method of disposal is not essential, but merely preferable, and in case of decision in favor of any other method, such as filling upon lowlands, burying, dumping into the lake, or utilization for fertilizer, a shift to electric power can be effected for the amount allowed in the estimate.

A steam plant as planned will consist of incinerating fire boxes, with provision for drying screenings or sludge, which materials will be burned in combination with coal fuel. The combustion gases will be led through dust arresters to the boilers and to a high stack.

In addition to the pumping equipment, the estimate includes provision for engine or motor-driven air compressors leading through receivers to sludge air lift pipes at the tanks. A venturi meter or other measuring device is also included in the pumping plant equipment.

Water will be obtained by an extension of the city mains.

Disinfection.—The plant for applying the disinfectant has been located adjacent to the main channel leading from the pumping station to the tank distribution system. The details are similar to those exhibited on plate 66, which is that of a typical design prepared to meet conditions at Bridgeburg, Ontario. In the present instance, however, it will be necessary to provide additional storage tanks, the number depending upon a proper balancing of labor and of construction charges. To guard against low winter temperatures it will be advisable to house in the tanks and to provide means for maintaining the temperature above freezing. A more detailed description of the apparatus is to be found in the text of the report relating to Bridgeburg.

Subsidence.—Although no examinations have been made, there is probably nothing notable about the sewage of Buffalo save its dilute nature. According to Fuller, dilute sewage requires a longer detention than does more concentrated material if equal or similar removal of suspended solids is to be attained. It is reasonably certain that prejudicial industrial wastes are not present in quantity sufficient to affect the whole. The tanning business has been canvassed and is apparently limited to handling some 4,000,000 hides per annum. The combined slaughtering and meat-packing business is a prominent one in Buffalo, but inquiry has failed to reveal any extensive slaughtering, the bulk of the industry apparently being confined to dressing or to the working up of final products. The chemical industry, which is confined to the neighborhood of Buffalo Creek, does discharge into sewers varied and diluted chemical wastes, principally such as result from the preparation of fertilizer and the manufacture of acids, but it is believed that the long distance of travel, combined with the large volume of diluting sewage, are sufficient to make any individual characteristics indistinguishable at treatment sites.

Consideration of subsidence devices has been limited to Emscher tanks, which it has been possible to so design as to apply to all four of the trunk sewer districts with but slight modification of minor dimensions as indicated upon plate 39.

A previous general statement to the effect that the size and number of tanks have been made adequate to retain for two hours 120 per cent of the 1930 average flow must be amplified by a statement of conditions obtaining during times of storm, for the sewers have been designed for 1950 maximum rates. The detention periods for these maxima are exhibited in Table 137.

TABLE 137.—*Imhoff tank detention of maximum flows, 1930, Buffalo, N. Y.*

Treatment works.	Average flow (cubic feet per second).	Maximum interceptor capacity (cubic feet per second).	Storm flow, minimum detention (hours).
South Buffalo	103	235.4	1.05
Swan Street	83.4	141	1.42
Bird Avenue	58.6	144.3	.97
Hertel Avenue	37.9	[1] 70	1.30
		[2] 95	.96

[1] Existing sewer. [2] Total 1950 capacity needed.

Minimum detention periods such as shown are in all cases sufficient to give time for the action of the disinfectant and also to secure appreciable subsidence. Parenthetically, were the nominal detention one hour, as elsewhere suggested, these relations would still give opportunity for disinfection, but would render doubtful any appreciable removal of organic solids.

Imhoff tanks.—As to details, the tanks follow many of recent design, though they are slightly longer than any yet built. They are 107 feet long and 35 feet 3 inches wide, with three interconnected flow-through channels having slots about 14 feet below weir levels. The total depth is variable for the different plants, but is in the vicinity of 25 feet from the weir. The individual tanks have been combined into groups having party walls and with influent and effluent channels at each end.

The distribution system has been planned as multiple channels with suitable stop-log control, and feed to low level influent conduits which discharge to the tanks through gate-controlled submerged orifices

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The effluent channel is above the influent line and receives the clarified sewage over a knife-edge weir which can be adjusted by means of turnbuckle screws.

The only special feature of the tank consists of the equipment of flood gates. As previously described, the bulk of lake and river fluctuations is found to occur below certain elevations, thus permitting of tank operation at such levels for the major portion of the year. At other times, and somewhat more frequently than is desirable to have treatment works out of commission, it is necessary to meet somewhat higher discharge elevations, thus rendering necessary the location of tanks at the higher level, or else special provision to permit of continued operation. The latter has been attained by carrying the main walls of each group some 3 feet above weir level and by cutting off the individual tanks to prevent short-circuiting by hanging at the tank ends wooden flap or flood gates. The use of such devices will enable the tanks to operate upon all but rare occasions, and at the same time will permit of a material saving in the pumping head. The pumps, of course, will have to be adequate for the maximum lift.

The construction of these tanks offers considerable difficulty, owing chiefly to the high ground water level. In addition, at South Buffalo, the site lies in the old bed of Buffalo Creek and is reputed to be underlaid with silt and quicksand deposits, with rock at quite considerable depth. A study of soil pressures discloses the fact that with uniform distribution the average pressure would be 1,600 pounds per square foot, which, with buoyancy allowance, reduces to 480 pounds per square foot, and when tanks are empty, to an upward pressure of 550 pounds per square foot. These loads are not great, but it has been deemed necessary to provide pile foundation. At Squaw Island the conditions are uncertain, but reasonably good foundation is expected, and though piles have been included in the estimate, the allowance is considerably less than at the southern site.

A schedule of construction operations prepared for estimate purposes includes the driving of a surrounding line of steel sheet piling anchored to timber piles, and inclusive of the whole tank area. Within the larger field it has been planned to drive subsidiary lines to inclose the various tank units. The excavation below ground water level can be done in the wet, as can the driving and cutting off of piles. Prior to dewatering it is expected that a concrete seal will be required. These features, together with liberal steam pumping allowance, have been included in the excavation item of the estimate, giving unit prices which are deemed adequate to the purpose.

Sludge beds.—With the tank elevations as fixed, the drawing off of sludge by gravity is not practicable. In the present instance it is expected that the air lift will be employed in vertical cast-iron pipes leading to an overhead system of galvanized iron pipes discharging to concrete distribution boxes, which connect with the sludge bed units. In order to preserve grade, the beds have been placed as close as possible to the tanks, and discharge directly to the river or through collector drains to the main outlet. The air-dried sludge will be handled in wheelbarrows and in tramcars, with ultimate disposal by incineration.

While the necessary tanks have been shown at Hertel Avenue, the proximity of dwellings render inadvisable the location of sludge drying beds at this point, for while the drying of sludge should not be in itself offensive, it is unsightly, and might well focus objections which would not appear were the process not thrust upon the attention. For this reason it has been planned to convey the wet sludge to Squaw Island for drying and for incineration. The two plants being between 1¼ and 1½ miles apart, the wet sludge can be transported by compressed air through a force main, or else it can be barged via the Erie Canal, which is 350 or 400 feet distant from the northern works. The second method has appeared preferable, and provision therefor included in the estimates. The barge, it is expected, would be of steel or concrete, self-propelled, and equipped with sludge pumps.

As to the effect of this double handling upon the drying qualities of the sludge, it is probable that the first use of the air lift will compensate for any loss of entrained gas occurring during the pumping operation.

The use of a barge to transport sludge limits this process to the period of open navigation. The Deep Waterways Commission Report of 1896 records 118 days per annum as the average period of close of navigation at Buffalo for the years 1876–1896. This interval includes that from December 12 to April 9, and is considerably less than that allowed for in the sludge storage capacity of the tanks. In other words, the tanks should be and are proportioned for non-drying weather conditions, the demands of which are in excess of the limitations fixed by navigation.

The treatment of sewage at centralized sites, while economic from the operative standpoint, imposes a burden in the need for proper final discharge in lake or river to the end of securing diffusion and dilution. This condition has been met by the adoption of multiple outlets consisting at South Buffalo of four lines of wood stave pipe, discharging at different distances from the shore. At the Hertel Avenue plant it is planned to utilize the existing river outlet which now accommodates this flow.

The outlet has been included in the estimates for the disposal plant, being regarded as an integral part of the treatment process, even though, as in the case of South Buffalo, it is distant from the plant itself.

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In the case of Buffalo, the proportioning of the number and sizes of screens is shown in Table 139, the basic data being applicable to Riensch-Wurl disk screens with $\frac{1}{32}$-inch slots and working under a 2-inch loss of head.

TABLE 139.—*Fine screens—Selection of sizes—Buffalo, N. Y.*

Treatment works.	1930 average flow (cubic feet per second).	Number and size of screens.	Total screen capacity (cubic feet per second).	Total interceptor capacity (cubic feet per second).	Overload during storm flow.
					Per cent.
South Buffalo	103	5-20 foot	128	235.4	84
Swan Street	83.4	3-20 foot 1-12 foot	86	141	64
Bird Avenue	58.6	2-20 foot 1-12 foot	61	144.3	137
Hertel Avenue	37.9	1-20 foot 1-14 foot	38	[1] 70 [2] 95	84

[1] Existing interceptor. [2] Future interceptor.

Upon the assumption that fine screening is in itself adequate for the removal of organic matter, there is no valid reason for subsequent sedimentation. If short time secondary sedimentation be needed to secure sufficient removal of solids, it is probable that the latter can be most economically attained from sedimentation alone as resulting from the longer periods of detention. Following these statements to their conclusion it is designed to disinfect the screen effluent in a long channel wherein the screened sewage will flow at a velocity to prevent deposition of the fine solids and for an average period of 30 minutes as the time required for contact. Such channels are cheaper to construct than tanks, are more readily cleaned when necessary, while the maintenance of carrying velocities obviates the continual handling and disposal of sludge.

It should be noted that at South Buffalo the sewage, subsequent to treatment, is discharged into an outfall line of such length that some 50 minutes will be consumed in reaching the harbor. This fact renders it possible to eliminate the contact channels at this site, although pronounced and sudden rises in lake level would at times cause an influx of diluting lake water which it might be necessary to offset by the use of additional disinfectant.

The South Buffalo fine-screen plan and estimate herewith presented are to be regarded as typical, inasmuch as they were prepared to serve as the basis for projecting the detail costs to totals for the whole city. The cost of the channels for this plant has been deducted from the gross total of the estimate.

COST ESTIMATES.

In appended tables are presented the estimates of cost for sedimentation and for fine screening, each in conjunction with disinfection. Sufficient detail has been shown to permit of readjustment of the total should further developments indicate the need for changing any of the individual items.

TABLE 140.—*Construction cost of Imhoff tank sedimentation, South Buffalo plant, Buffalo, N. Y.*

Main item.	Subdivision of work.			Total cost.
	Amount.	Unit price.	Cost.	
Coarse screen...	Excavation, 1,540 cubic yards	$2.35	$3,619	
	Concrete, 197 cubic yards	12.25	2,413	
	Screen, 3.4 tons	55.00	187	
				$6,219
Grit chamber and pump well.	Excavation, 4,420 cubic yards	1.65	7,293	
	Concrete, 590 cubic yards	10.80	6,372	
	Appurtenances		1,030	
				14,695
Mechanical plant.	Pumps and engines		16,000	
	Boilers and incinerators		13,500	
	Buildings and piping, 143,000 cubic feet.	.15	21,450	
	Railroad siding and coal bins, 90 tons.		12,000	
				62,950
Disinfection plant.	Building, 34,000 cubic feet	.20	6,800	
	Tanks, 200 cubic yards	13.15	2,630	
	Equipment		1,570	
				11,000
Imhoff tanks...	Excavation, 99,000 cubic yards	2.20	217,800	
	Tank, concrete, 530 cubic yards	12.65		
	Floors, 1,290 square yards	2.00		
	Appurtenances	875.00		
	Total, 1 unit	10,160.00		
	24 units	10,160.00	243,840	
	Piping		18,360	
				480,000
Influent channels.	Concrete, 380 cubic yards	12.50	4,750	
	Appurtenances		450	
				5,200
Effluent channels.	Excavation, 4,900 cubic yards	1.50	7,350	
	Masonry, 1,530 cubic yards	9.10	13,923	
				21,273
Sludge beds....	Excavation, 5,160 cubic yards	.70	3,612	
	Concrete, 680 cubic yards	10.45	7,106	
	Gravel, 3,720 cubic yards	1.25	4,650	
	Underdrain and track		2,300	
	Railway		1,500	
				19,168
Outlet	5,200 feet 6-foot	11.20		58,240
Land	9.3 acres	7,500		69,750
	Total			748,495

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plicable to a town of 10,000 people, gives a range of from $0.98 to $1.95 per capita.

In summary, and also to express the costs in terms of certain units, Table 143 is presented.

TABLE 143.—*Construction cost of sedimentation—Summary and subdivision—Buffalo, N. Y.*

Plant.	Total cost.			Coarse screens and grit chambers.			Imhoff tanks.[1]			Sludge beds.			Disinfection.	
	Totals.	Per M. G.D.	Per capita.	Total.	Per M. G.D.	Per capita.	Total.	Per M. G.D.	Per capita.	Total.	Per M. G.D.	Per capita.	Total.	Per M. G.D.
South Buffalo	$748,495	$11,240	$3.80	$20,914	$314	$0.106	$506,473	$7,610	$2.57	$19,168	$288	$0.097	$11,000	$165
Squaw Island	[2]1,026,369	[2]11,170	[2]3.03	21,970	239	.065	718,000	7,820	2.12	[2]22,370	244	[2].066	17,080	186
Hertel Avenue	262,417	10,730	3.92	8,947	366	.134	209,300	8,560	3.13	19,200	785	.287	4,470	183
Total	2,037,281			51,831			1,433,773			60,738			32,550	
Average		11,140	3.38		283	.086		7,840	2.38		332	.101		178

[1] Includes Influent and Effluent Channels. M. G. D.=1930 average flow (Table 135).
[2] Includes Hertel Avenue sludge beds.
[3] Excluding Hertel Avenue sludge beds. Per capita=1930 population (Table 135).

TABLE 144.—*Construction cost of fine screens, South Buffalo plant, Buffalo, N. Y.*

Main item.	Subdivision of work.			Total cost.
	Amount.	Unit price.	Cost.	
Coarse screens, grit chamber, and pump well.	Same as for Imhoff tanks (see Table 140).			$6,219 14,695 62,950
Mechanical plant...				
Disinfection plant..	Buildings, 40,000 cubic feet	$0.20	$8,000	
	Tanks, 250 cubic yards	13.15	3,288	
	Equipment		1,712	
				13,000
Fine screen plant...	Excavation, 3,100 cubic yards	1.60	4,960	
	Substructure, 1,250 cubic yards...	9.75	12,188	
	Building, 5,040 square feet	.75	3,780	
	Screens, 5	28,400	142,000	
	Appurtenances		2,072	
				165,000
Detention channels.	Excavation, 16,445 cubic yards...	1.95	32,067	
	Concrete, 2,370 cubic yards	11.65	27,610	
	Appurtenances		2,653	
				62,330
Outlet	5,200 feet, 6-foot	11.20	58,240	
	240 feet, 8½-foot	22.10	5,304	
				63,544
Land	4.2 acres	7,500		31,500
	Total			419,238

A comparison between the construction costs of fine screen and of Imhoff tank installations indicates that the latter would be the more expensive by about $1,144,000. In interpreting these figures, it should be recalled that the tanks have been proportioned for a nominal detention of 2.4 hours for the 1930 average flow, yielding a minimum detention of 58 minutes in time of storm, when the interceptor will be discharging at the 1950 maximum rate. Screens, on the other hand, have been selected to meet the 1930 average flow, operating "full" with a 2-inch loss of head. Operation at full depth is made possible by placing the screens after the pumps, where, by adjustment of gates, etc., the proper depth can be maintained. In time of storm this leads to an overload of from 64 to 137 per cent, which in turn causes a somewhat greater loss of head, with probable diminution in the retention of finer solids, though it is possible that this tendency might be counteracted by increased speed of screen operation. On the other hand, it is necessary that the detention channels give, even for maximum flows, a sufficient time for the action of the disinfectant, and they have accordingly been designed to hold for 15 minutes the 1950 maximum discharge. As to the comparative efficiencies of these two processes under the varying conditions, experiment alone will tell, but it is believed that further experience will indicate the necessity for a somewhat more liberal screen allowance. The present provisions are offered as a minimum.

TABLE 145.—*Construction cost of fine screens, whole city, Buffalo, N. Y.*

Treatment works.	Average sewage flow, 1930, M. G. D.	Coarse screens, grit chamber, pumps, outlet.	Fine screens.	Disinfection, channels, buildings, and land.		Total.
				Total.	Per M. G. D.	
South Buffalo	66.6	$147,408	$142,000	$129,830	$1.950	$419,238
Squaw Island	91.8	75,400	[1]165,000	179,000	1.950	419,400
Hertel Avenue	24.5	25,547	[2]43,000	48,000	1.950	116,547
Total	182.9	248,355	350,000	356,830		955,185
Deduct South Buffalo detention channels						62,330
Net total						892,855

[1] 5 20-foot screens=$100,000
2 12-foot screens= 18,000
118,000
Installation, 40 per cent, 47,000
165,000

[2] 1 20-foot screen= 20,000
1 14-foot screen= 11,000
31,000
Installation, 40 per cent, 12,000
43,000

Operation.—The first cost, or the cost of construction, is important in aiding determination as to the financial ability of the city to undertake the work, but of equal importance is the yearly cost of operation, and to render possible an economic comparison of these two projects it is necessary also to include allowances for

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upkeep, interest upon bonds, and amortization, leading, in combination with labor and material costs, to comparable annual charges. These items are presented in the following tables, which include labor at $2, firemen at $3.50, and engineers at $4.50 each per day of eight hours. Superintendence and technical help have also been added, to the extent of $7,800 for the tank plants and $6,000 for the fine screen plants.

TABLE 146.—*Annual operation costs, Imhoff tank plants, Buffalo, N. Y.*

Treatment works.	Subdivision.	Annual operation.						Total.	
		Coarse screens.	Grit chambers.	Pumps.	Disinfection.	Tanks.	Sludge.		
South Buffalo	Labor	$1,771	$1,334	$14,095	$3,318	.....	$5,340	$25,858	
	Materials	.....	.....	7,136	37,040	.....	.....	44,176	
									$70,034
Swan Street	Labor	1,598	1,007	13,695	3,000	$1,095	3,995	24,390	
	Materials	.....	.....	2,035	31,485	.....	.....	33,520	
									57,910
Bird Avenue	Labor	1,735	870	.....	2,057	.....	4,160	8,222	
	Materials	.....	.....	.....	22,206	.....	.....	22,206	
									31,028
Hertel Avenue	Labor	1,558	389	5,239	1,170	390	2,390	11,136	
	Materials	.....	.....	3,594	13,655	.....	54	17,303	
									28,439
Total	.....	.....	.....	.....	.....	.....	.....	.....	187,411

TABLE 147.—*Annual operation cost, fine screen plants, Buffalo, N. Y.*

Treatment works.	Subdivision.	Yearly costs.					Total.	
		Coarse screens.	Grit chambers.	Pumps.	Disinfection.	Fine screens.		
South Buffalo	Labor	$1,614	$1,219	[1] $12,600	$4,582	$9,764	$29,779	
	Materials	.....	.....	7,136	52,634	802	60,572	
								$90,351
Swan Street	Labor	[1] 1,456	[1] 920	[1] 12,240	[1] 4,140	[2] 7,800	26,556	
	Materials	.....	.....	2,035	[1] 44,750	[2] 650	47,435	
								73,991
Bird Avenue	Labor	[1] 1,582	[1] 796	.....	[1] 2,840	[2] 5,560	10,778	
	Materials	.....	.....	.....	[1] 31,550	[2] 458	32,008	
								42,786
Hertel Avenue	Labor	[1] 1,420	[1] 355	[1] 4,685	[1] 1,805	[2] 3,290	11,555	
	Materials	.....	.....	3,594	19,400	[2] 270	23,264	
								34,819
Total	.....	.....	.....	.....	.....	.....	.....	241,947

[1] Increased from tank item in same ratio as computed for South Buffalo.

[2] Computed from South Buffalo cost per M. G., 1930 average flow.

TABLE 148.—*Annual fixed charges, Imhoff tank plants, Buffalo, N. Y.*

Treatment works.	Interceptors.	Structures.	Land.	Machinery.[1]	Total.
First cost:					
South Buffalo	.....	$593,598	$69,750	$85,147	$748,495
Swan Street	.....	452,787	99,200	55,182	607,169
Bird Avenue	.....	313,600	64,400	22,000	400,000
Hertel Avenue	.....	216,175	30,900	34,542	281,617
	$1,561,470	.....	.....	.....	1,561,470
Total	1,561,470	1,576,160	264,250	196,871	3,598,751
Annual fixed charges:					
Interest at 4½ per cent	70,266	70,927	11,891	8,860	161,944
Amortization	[2] 2,139	[3] 8,826	1,480	[4] 19,687	32,132
Maintenance and repairs	1,500	7,881	.....	.....	9,381
Total	73,905	87,634	13,371	28,547	203,457

[1] Includes, in addition to pump-house machinery, all piping, valves and track.
[2] 80-year life at 4½ per cent.
[3] 50-year life at 4½ per cent.
[4] Combined amortization and repairs allowance at 10 per cent.

TABLE 149.—*Annual fixed charges, fine screen plants, Buffalo, N. Y.*

Treatment works.	Interceptors.	Structures.	Land.	Machinery.[1]	Total.
First cost:					
South Buffalo	.....	$136,908	$31,500	$188,500	$356,908
Squaw Island	.....	148,622	76,300	194,438	419,400
Hertel Avenue	.....	44,992	14,000	57,555	116,547
	$1,561,470	.....	.....	.....	1,561,470
Total	1,561,470	330,562	121,800	440,493	2,454,325
Annual fixed charges:					
Interest at 4½ per cent	70,266	14,875	5,481	19,822	110,444
Amortization	[2] 2,139	[3] 1,851	[2] 683	[4] 44,049	48,722
Maintenance and repairs	1,500	1,653	.....	.....	3,153
Total	73,905	18,379	6,164	63,871	162,319

[1] Includes pump-house machinery, piping, screens, railway, etc.
[2] 80-year life at 4½ per cent.
[3] 50-year life at 4½ per cent.
[4] Combined amortization and repairs at 10 per cent.

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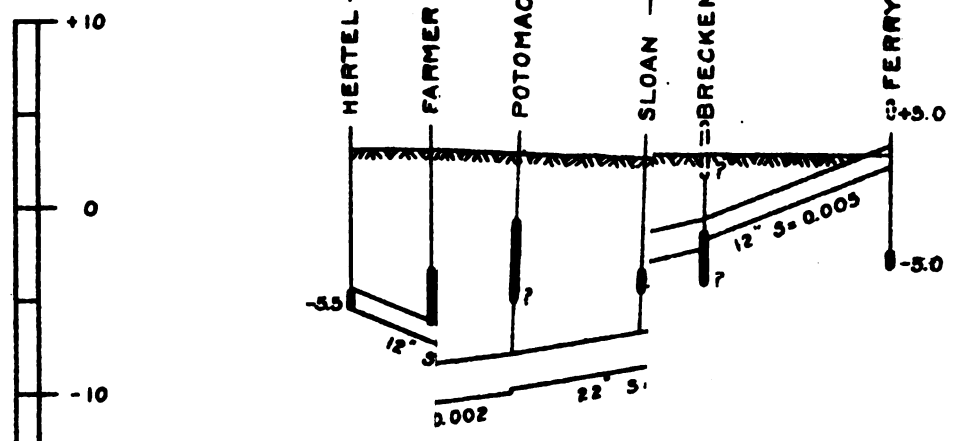

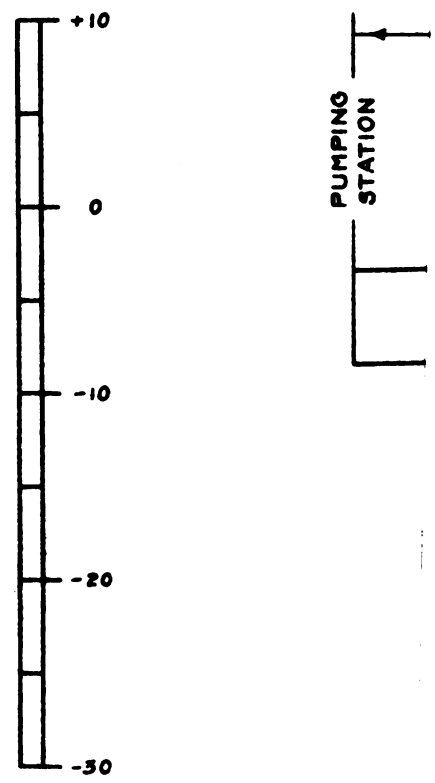

. N.Y.

INT PROFILES

D

800 FT.

C.Z.W.

...ING PETERS CO., WASHINGTON, D. C.

Plate 42

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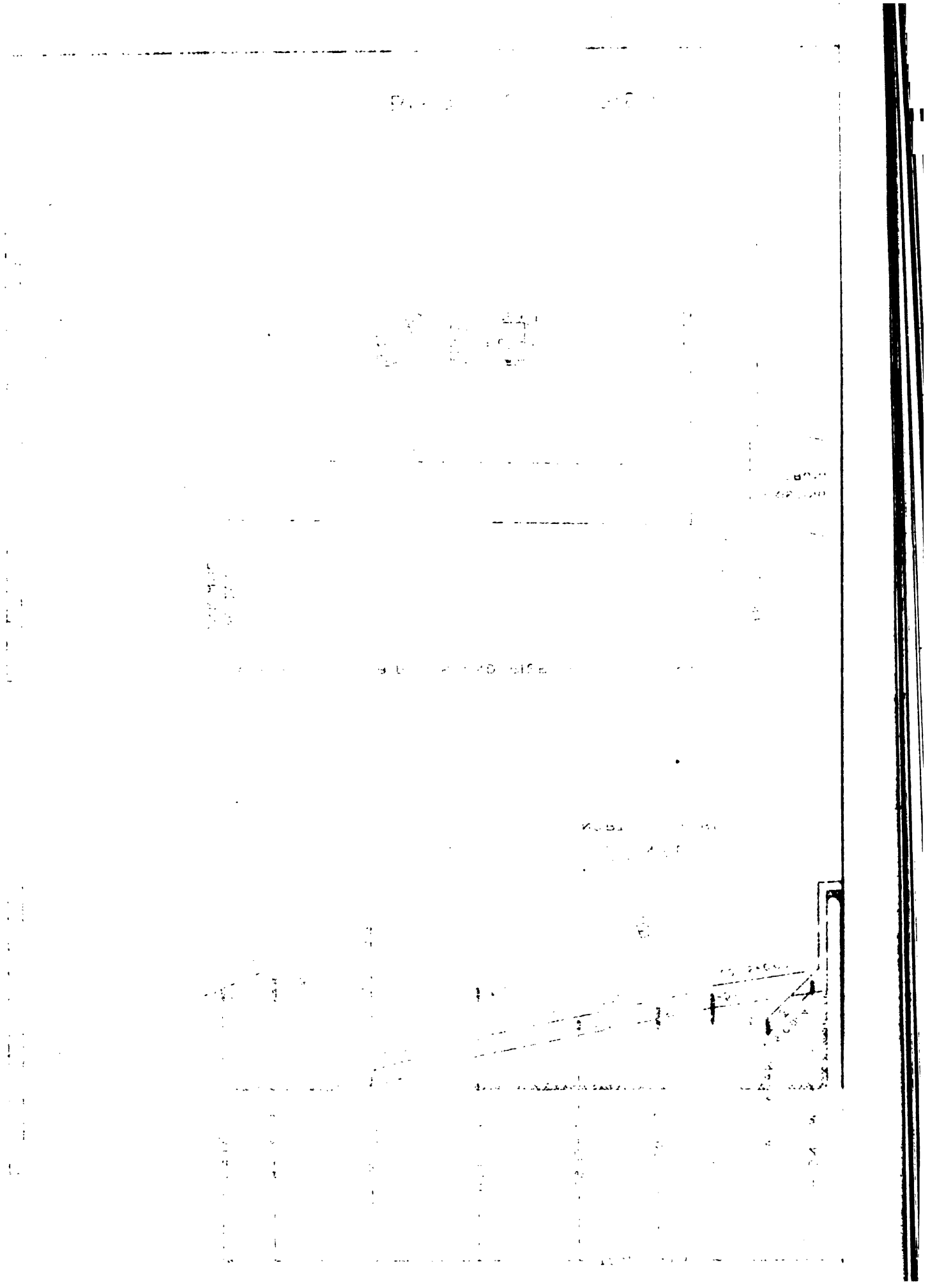

struction of some 2,000 feet of 24-inch vitrified pipe interceptor, with 18 and 20 inch connections to the respective trunk lines, and with a 24-inch cast-iron pipe crossing of the canal. The 24-inch size will accommodate not only the sewage flow from the Franklin Street district, but is also adequate to permit of future extension to a southerly outlet for as yet undeveloped territory.

TREATMENT.

The treatment works designed as applicable to local conditions have followed the general lines of the Niagara River report, and include provision for a small grit chamber and coarse screen, which will serve to remove only the bulkier solids. The tanks being located at sufficient elevation to secure gravity discharge into the river, and at such heights as not to be subject to ordinary river rises, it will be necessary to handle the sewage through automatically operated motor-driven centrifugal pumps. Subsequent to passage through the pumps, the sewage will receive its dose of disinfecting liquid and pass to the Imhoff tanks which, because of the high per capita flow, can be most economically constructed in circular units, of which a total of six will be required for the 1930 needs. As shown by plate 47, the discharge to these tanks is accomplished through a trough attached to an internal collar concentric with the periphery of the tanks and forming the air vent of the sludge compartment. Inflow occurs through slots in the weir, while the clarified sewage discharges over an outlet weir which encircles the external periphery of the tank. Control of the water level can be effected by throttling the outlet line or by means of rotary shutters situated on the weir, as shown. The tank overflow connects with the existing outlet section of the Bouck Street sewer, which discharges into the river at a considerable distance from shore. As before suggested, provision has been made for removing the sludge periodically by means of a centrifugal pump which will force the liquid about a mile to drying beds in the valley of Two Mile Creek, at which point the air-dried product can be readily removed and used either for filling or as fertilizer on near-by farms.

COST.

The first cost of construction has been estimated as indicated in Table 152.

TABLE 152.—*Tonawanda, N. Y.—Cost, interceptor and treatment works.*

Item and quantity.	Unit cost.	Cost.	Total cost.
Interceptor: 2,465 lineal feet, 18, 20, and 24 inch sewer	$6.50	$16,023	$16,023
Treatment:			
Grit chamber and pumping station			
Pumping equipment			
Disinfection plant:			
Building, 25,000 cubic feet	0.17	4,250	
Tanks		372	
Equipment		1,215	
Imhoff tanks:			
Excavation, 965 cubic yards	1.70	1,640	
Concrete, 160 cubic yards	13.00	2,080	
Appurtenances		350	
Total, 1 unit		4,070	
6 units		4,070	
Influent channels, 50 cubic yards	12.00	600	
Effluent pipes, 300 lineal feet	1.75	525	
Sludge beds and force main			
Land, 3 acres	3,000	9,000	
Miscellaneous: Water pipe, planting, roadway			
Total			
Fixed charges at 6 per cent			

Operation has been estimated and subdivided as follows:

Power	$1,0
Labor, at $5.84 per day	2,1
Disinfection, at $7.59 per day	2,7
Superintendence	8
Total per annum	6,0

CONCLUSION.

In the event that conditions be imposed upon the Niagara frontier communities leading to such treatment of their sewage as would be effected by subsidence in Imhoff tanks and by disinfection, the city of Tonawanda could conform to such regulations by an initial expenditure of not more than $70,000, and an annual maintenance cost for material, labor, and fixed charges of about $10,900.

ACKNOWLEDGMENT.

The interest of city officials in the work of the Commission has been marked. Particular assistance has been rendered by Messrs. James Conway and B. Hinkey, respectively superintendent of public works and city engineer.

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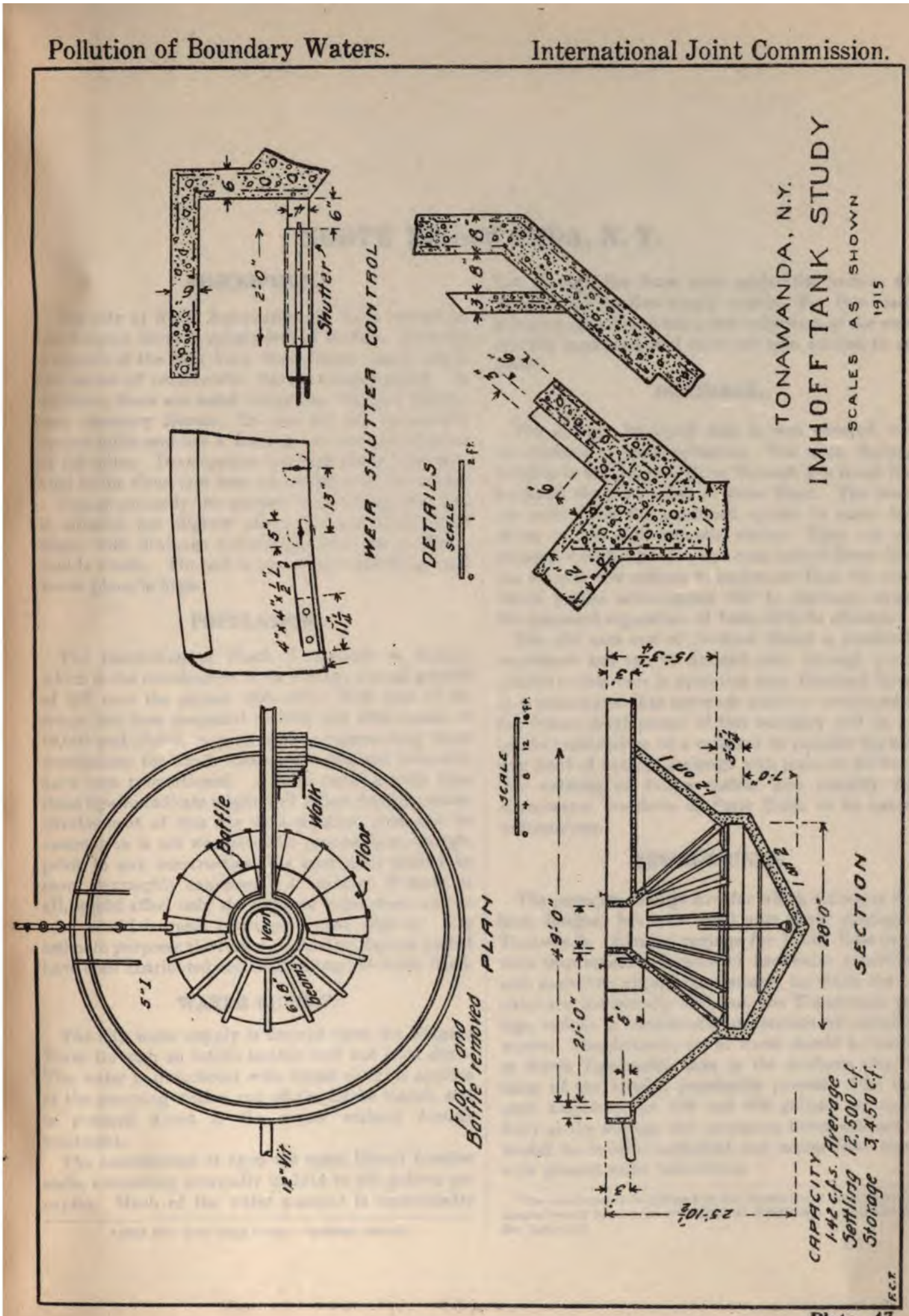

Plate 47

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TREATMENT SITE.

The site selected for the location of treatment works fronts the east side of River Road and is some 1,700 feet north of Wheatfield Avenue, although its exact position is unimportant. The factors leading to this determination are the central location, which serves to minimize pumping, and its proximity to a suitable outlet. Opposed to the choice are its nearness to a main thoroughfare, the presence of dwellings (1,000 feet distant), and the high land values. These objections apply in some degree to any water-front location and can be avoided only by an inland plant, which would entail a force main extension of interceptors or else would require a remodeling and reversal of present sewerage. In either case expense forbids for any desirable site would be at some distance from the sewered area and pumping requirements would be severe. Similarly the possibility of locating near to the north city line in sparsely settled area was rejected on the score of increased pumping, and because it was felt that the present undeveloped condition of this section was but temporary and that with future growth the objections previously stated would apply with equal force as to a more southerly situation. A site on Tonawanda Island adjacent to the pumping station is attractive in many ways, but is less economic than that favored.

Imhoff tanks properly designed and operated should give no offense, and if due attention be given to care of the grounds and if in addition sludge beds be screened from view by appropriate shrubbery a River Road treatment works location should not be objectionable. At Tonawanda the possibility of protest has been forestalled by provision for pumping the sludge to drying beds more remotely placed. Similar provision could be included in the present instance at an additional initial expense of about $6,500.

In this discussion no mention has been made of the possibility of treating at separate local works. Such procedure is feasible and would save $38,200 in interceptor and outlet construction (see Tables 154 and 155). On an annual charge basis this amount is equivalent to $1,825. In addition, there would be saved about half the pump power needed for a central site, or (Table 157) $1,000. The amount of $2,825 then represents the annual saving of dual sites in the items of interceptor construction and pump operation. To offset this is the need for duplicate plant construction including such items as grit chamber, pump house, disinfection apparatus, and also some loss of economy in tank and sludge bed construction and in the utilization of land. These items are estimated to aggregate $16.000, equivalent to an annual charge of $1,400. Adding to this additional labor to the extent of $640, the initial saving reduces to an annual amount of $785, or to a capitalization of $17,500. This economy is tangible, but lessens in importan
count is taken of the increased cost of str
through the loss of an interceptor outlet
between Wheatfield Street and East A
this reason, as construed in the belief th
described will shortly require an addition
let, the conclusions of this report have
upon the treatment of sewage at one site.
clusions will give outside costs and lea
tion to be settled by more detailed studi

INTERCEPTORS.

To gather the sewage from the five exi
and to conduct it to the treatment site fix
ceptor has been planned to traverse the we
of city development. As shown upon p
line starting at Bond Street follows Manh
north to the State ditch, crosses to an a
Main Street, and extends to Island: the
Island to River Road and northerly to
At each end the terminating size is suffic
mit of future extension as needed. The
scribed will intercept the sanitary wast
whole city, together with an unknown p
storm run-off. West of this location, bet
the river, lies a lumber-yard area, the dr
which—as well as that from Tonawand
neglected as being practically nil.

From a construction viewpoint, the
scribed is favorable, the southerly portio
unpaved streets, and the northerly portio
the River Road, which, though designe
proved as a State highway, possesses s
sufficient width to enable the constructio
sewer without disturbance to the roadwa

As before explained, the ground is qui
the case of a sewer several miles in leng
dition leads either to a very deep line a
end, or else to provision for pumped ste
hydraulic grade. Pumps accordingly ha
cated at Bond Street, at Schenck Street,
Street, thus permitting of delivery to th
works at a depth of 16 feet below the su
also is the depth of maximum cut.

The installation of these pumps adds
struction cost, but not very materially, a
of operation is largely offset by a dec
main pumping station lift over what
from gravity delivery to the treatment wo

Despite provision for frequent lifts, n
interceptor will be located below ground
The difficulties of securing tight joints in
laid in water-bearing soil are considerabl
much as it is desirable from the viewpoint
to reduce to a minimum the amount of g
passing through the pumps and through t

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International Joint Commission.

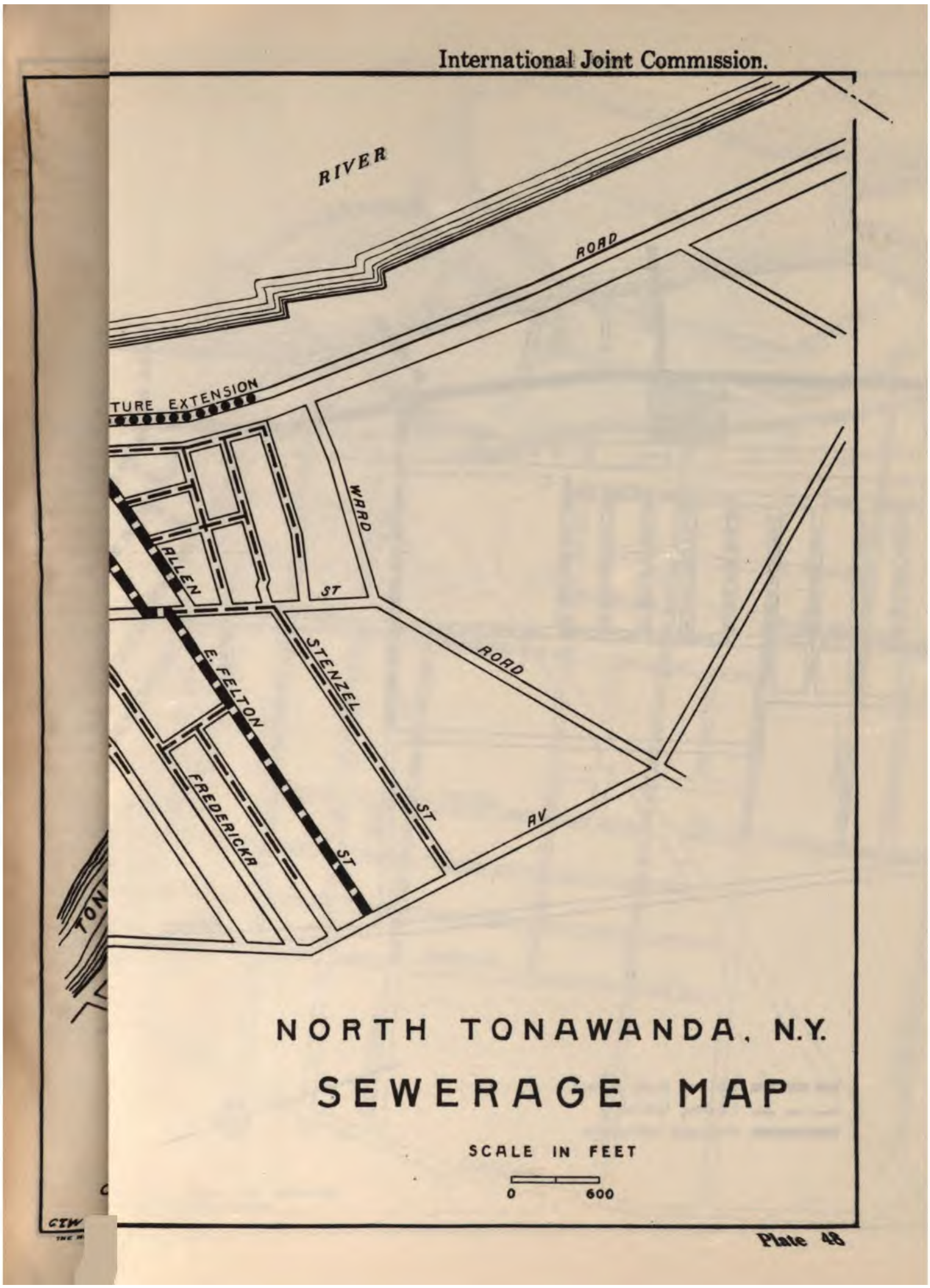

Plate 48

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The general features of the plant are apparent from an inspection of plate 50. From the two interceptors the sewage will pass to a small grit chamber intended for the removal of such coarse mineral matter as may settle with a slight slacking of velocity. The lower end of the grit chamber is fitted with coarse screens through which the sewage will pass to the pumps. The pump discharge line is in open channel leading through the disinfection house to the settling tanks which will permit the clarified sewage to run to a river outlet.

ELEVATION.

The tanks are set at such elevations as will insure gravity discharge to the river even at periods of high water. The sludge drying beds are set at the same level, which will necessitate additional pumping, but inasmuch as the pumping of sludge is less expensive than pumping the sewage from which it has settled, the elevations fixed are the most economical. The river stages met are those which will result should the recommendations of the Waterways Commission be carried out.

GRIT CHAMBER.

The grit chamber shown in the general ground plan is smaller than those favored in the best practice. The departure is made because the structure is necessarily located at and below interceptor depth, which for a tank of usual size would entail considerable expensive excavation. It is recognized that this plan will permit much nonputrescible detritus to enter the Imhoff tanks which could be removed otherwise. This material, however, will be too finely divided to hinder tank operations, and may, indeed, improve the draining character of the sludge.

The screen it is proposed to make of the usual inclined bar type with 2-inch openings. Screenings will be raked off by hand and either buried or removed with the sludge.

Chambers, screens, and pump wells—the latter in reality a sump—will be installed in duplicate to permit of frequent cleaning which will be accomplished by hand, buckets of grit being lifted by a chain hoist and used to replenish sludge beds, or else hauled away to spoil banks.

PUMP HOUSE AND DISINFECTION.

The pumping plant will consist of 12-inch centrifugal pumps driven by float-controlled electric motors. Automatic control is chosen to permit of divided duties upon the part of the attendant. The pumps will not include a reserve unit, but each unit will have considerable surplus capacity, so that a breakdown will entail but a backing up in the interceptors for greater or less time.

From the pumps the sewage will be carried in open channel over a measuring weir to the disinfecting house, where a continuous and a
trolled dose of bleach will be app
of the construction and operation o
plant, reference is made to the port
relating to Bridgeburg, Ontario.

TANKS.

The tank outlined in plate 50 is
vide nominal retention of flow fo
sludge storage capacity to the exten
per capita. The tank is of the radi
collection of the clarified effluent by
lector ring. Weir control devices a
can be employed as illustrated on pla
storage is designed to permit of slu
nondrying winter months.

Sludge will be removed at interva
which will be in extension of a n
pressor located in the pump house.
tank level, the sludge will flow to
where it will drain and air dry.
will be removed at intervals and d
country either to farmers for its fe
else used for filling.

OPERATION.

The plant as described will requ
the extent of at least three labore
arranged that one man will be or
hours of the day. The duties of suc
raking of screens, cleaning of gri
sional control of pumps and distr
mixing of bleach, pumping of sludg
sludge beds.

COST.

Estimates have been prepared of
structing and operating the works
costs are complete, including allowa
royalties, and for engineering. T
in tabular form.

TABLE 154.—*Construction costs and fixed*
tors, North Tonawanda, N

Item and quantity.	
500 lineal feet 4-inch C. I. pipe	
2,150 lineal feet 15-inch vit. pipe	
3,220 lineal feet 18-inch vit. pipe	
1,000 lineal feet 22-inch vit. pipe	
650 lineal feet 24-inch vit. pipe	
970 lineal feet 27-inch vit. pipe	
1,580 lineal feet 33-inch masonry sewer	
3 automatic pumps	
Total construction	
Interest charges, at 4½ per cent	
Amortization, 30 years, at 4½ per cent	
Maintenance	
Total annual fixed charges	

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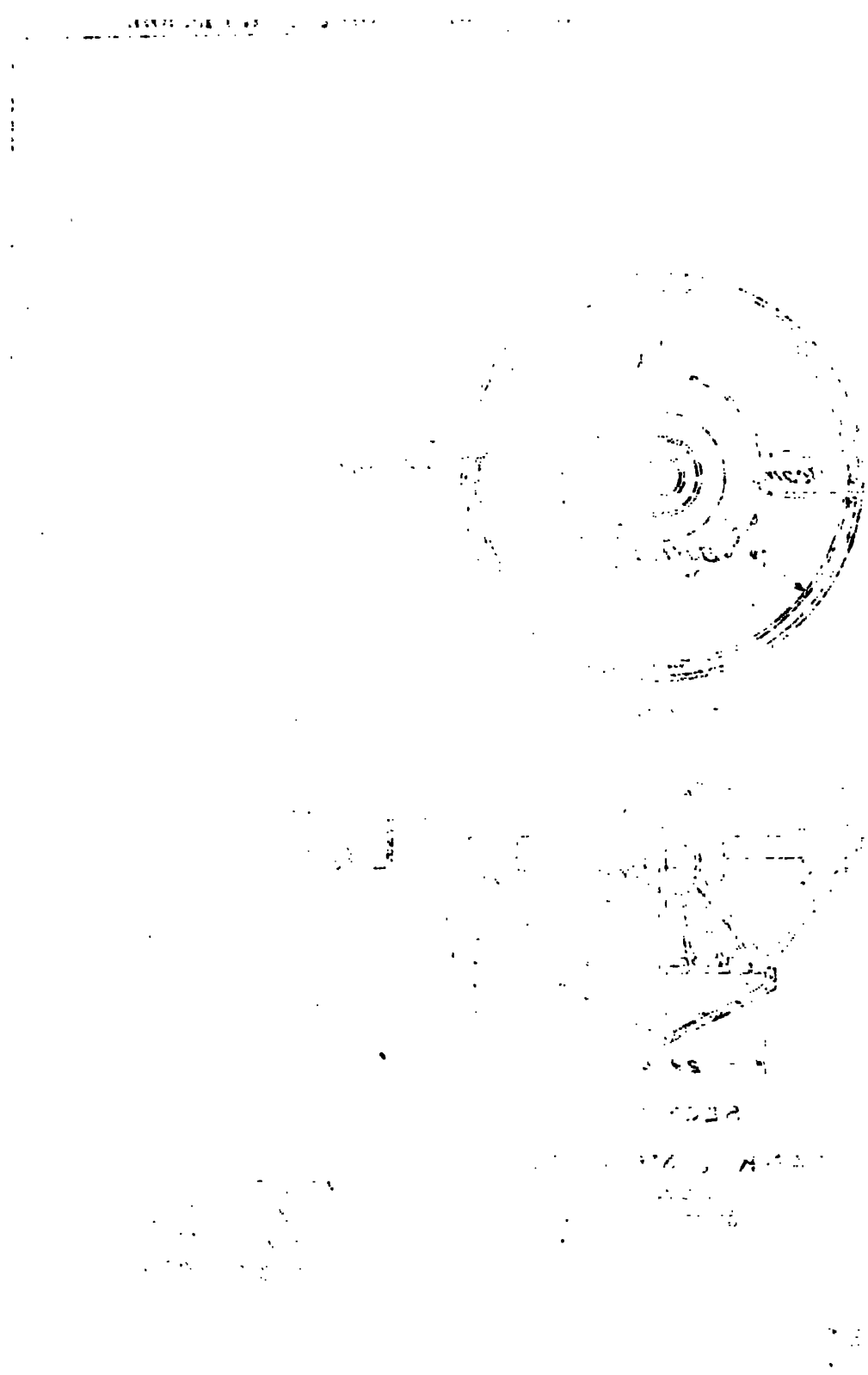

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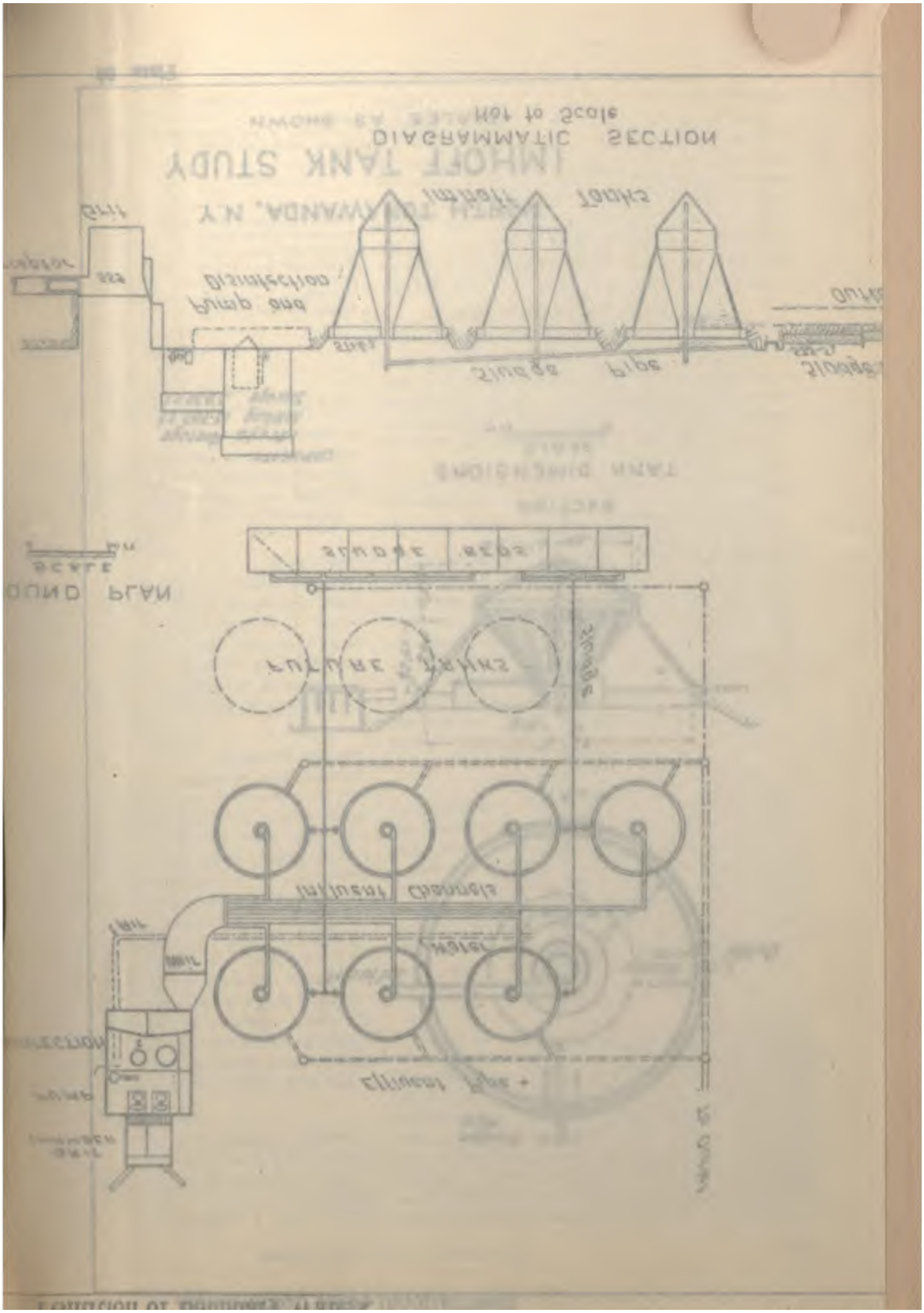

waters. The sewerage outlined in this report is therefore only in skeleton, consisting entirely of a collecting sewer, which, however, can be extended at need. For this reason neither the two plans nor the cost estimates therefor are comparable.

As before noted, the population of La Salle is at present localized at two centers, with an intermediate portion of sparse development. Accordingly it has seemed preferable, as it is economic, to treat the sewage at two points, utilizing the existing settling tank which now handles the sewage from the northern portion of the village. Under this plan it is possible to eliminate the present construction of at least a mile of interceptor, although provision has been made for its extension, with ultimate abandonment of the northern plant.

The northern plant referred to drains what is known as the Evershed tract. It consists of a tank about 5 feet by 8 feet in plan and 6 feet deep below water line. It is housed over and has wired connections for a motor-driven pump. The tank, with the connecting sewers, was built in 1897, and is sufficient to offer a 24-hour detention of sewage. It has been the practice to clean the tank yearly, the operation as well as the original construction having been at the instance of the late E. P. Bowen.

Mr. Wilson's report, previously alluded to, involved treatment of sewage in septic tanks and contact beds, at a site adjacent to the River Road and to the bridge connecting the mainland with Cayuga Island. This site is perfectly feasible, but owing to its proximity to a summer hotel and to a thoroughfare which is much used by residents of summer camps on the Island it has seemed preferable to move the plant toward the north, where abundance of land is available. Also, because of the narrowness of the marginal strip between the River Road and Cayuga Inlet, it has seemed desirable to locate the disposal works on the northerly point of Cayuga Island itself, although this situation involves the construction of a costly pipe line under the inlet.

The lengths of the collector lines, combined with the flatness of the ground slopes, render deep construction necessary, or else require the use of booster pumps. Comparative estimates of these alternatives leads to a decision in favor of pumping, as not only being more economic in ultimate cost, but also as offering less trouble from ground water infiltration, and as being more convenient for house drain connections.

For present needs an interceptor in Military Road and in River Road from Creek Road to Duane Street, together with a short branch to the southerly side of Cayuga Creek, will suffice, and estimates have been based thereon, utilizing for purposes of profile the original Busch & Percival map of La Salle. This plan omits interception from three small drains at the easterly edge of the village, as it is more economic to suppress the use of these sewers for sanitary purposes until such time as the development of this territory warrants interceptor extension. There will also be missed a small sewer in the Rosedale subdivision, which now contains two or three houses. In the northern section, immediately abutting the Niagara Falls city line, the sewerage is now complete.

Profiles of the line described have not been included in this report, because of the absence of adequate data, but the general route is as shown upon plate 52, and the quantities as shown in Table 158.

TABLE 158.—*Estimate of maximum sewage quantities 1950, sewer sizes, La Salle, N. Y.*

Location.		1950 accumulated population.	Sewage, at 350 G. C. D.[1]		Sewer.			
							Velocity.	
In—	At—		M. G. D.[2]	C. F. S.[3]	Size, inches.	Grade.	Full, feet per second.	1915, minimum feet per second.
Southern Branch.								
Military Road.....	Creek Road.	400	0.14	0.2	8	0.006	2.0	0.6
	Griffon.....	1,440	.52	.8	8	.006	2.0	1.2
					10	.004	2.0	1.1
River Road.....	Railroad....	1,960	.69	1.1	10	.004	2.0	1.1
					12	.003	2.0	1.1
	Burdette....	2,700	.95	1.5	12	.003	2.0	1.1
	Hamilton...	3,510	1.23	1.9	12	.0045	2.4	1.3
Northern Branch.								
River Road.....	Duane.....	2,930	1.02	1.6	....	.....	.....	.....
					12	.0045	2.4	1.3
	Hamilton...	3,400	.....	.....	....	.....	.....	.....

[1] G. C. D.=gallons per capita daily.
[2] M. G. D=Million gallons daily.
[3] C. F. S.=Cubic feet per second.

Pumping, where necessary, it is planned to accomplish by small automatic centrifugal pumps situated in manholes and driven by a small motor located well above the water line. The automatic feature lies in the control switch for the motor, which is actuated by a float rising and falling with the level of sewage in the sewer. Details of such a scheme, together with a fuller description, are to be found in the portion of this report devoted to the situation at North Tonawanda. Altogether, two pumps will be needed in addition to the major installation at the treatment site.

Even with the aid of the booster pumps it will be impossible to entirely avoid construction below ground water, and inasmuch as all the sewer sizes are of pipe dimensions, it has seemed proper to include in the estimate an allowance for an enclosing jacket of concrete to withstand external hydrostatic pressure.

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TREATMENT.

The sewage treatment planned involves the use of an Imhoff tank coincident with the application of disinfecting liquid. Included also are coarse screens and sludge drying beds. The tank has been made rectangular in plan, with three flow-through chambers connecting to three pyramidal sludge pockets. Owing to the high ground water level, this tank has been made exceedingly shallow, which adds to the cost of construction. The upper compartment has been proportioned to retain the average flow for 2.4 hours, while the digestion chamber has been designed on the basis of 1 cubic foot per capita. Provision has been made for reversing the flow of sewage, the weirs at both ends being in duplicate and fitted with galvanized iron swing gates which will serve to throttle the flow at the influent weirs. The grit chamber for this installation has been made exceedingly small, amounting to little more than a pump well, which will remove only the heavier portions of the grit. This is justified by the probability that the sewerage in La Salle will be of the sanitary type with opportunity for the admission of but little road detritus.

It should be understood that the design shown on plate 53 is not essentially final. It is merely a suggestion upon which an estimate has been based as providing funds sufficient for any similar type of construction, whatever may be the detail dimensions and features thereof.

COST.

The cost of the collectors and treatment works as outlined is shown in Table 159.

The maintenance of both of these plants, together with occasional inspection of the collector and auxiliary pumps, will require the constant attention of one man, and should amount to not more than $1,500 per year, if due economy in the application of the disinfecting chemical is obtained.

CONCLUSION.

The existing situation at La Salle is such as to demand attention in the near future, the present drainage of untreated sewage into Cayuga Creek and adjoining waters giving rise to a local nuisance and to the pollution noted in the Progress Report as obtaining at this point. Remedies for the relief of this pollution can be installed as described, to fit in with the future development of municipal sewerage, at a first cost of not to exceed $40,000, and at an annual maintenance cost for labor and materials and fixed charges of about $3,820.

TABLE 159.—*Estimate of cost, collector and treatment works, La Salle, N. Y.*

Item.	Quantity.	Unit cost.	Cost.	Total cost.
Collectors:				
Excavation	9,500 cubic yards	$1.00	$9,500	
Pipe, vitrified—				
8-inch	2,460 feet	.18	443	
10-inch	840 feet	.26	218	
12-inch	4,630 feet	.35	1,620	
Pipe, cast-iron	16.75 tons	37.00	620	
Creek crossings			2,500	
Concrete, etc	868 cubic yards	5.90	5,120	
Manholes—				
Drop	10	86.00	860	
Standard	15	75.00	1,125	
Flushing	3	135.00	405	
Pumps	2	1,290.00	2,580	
				$24,9[illegible]
Pump well and pumps				2,5[illegible]
Disinfection plant				1,0[illegible]
Imhoff tanks:				
Excavation	1,000 cubic yards	2.44	2,440	
Concrete	200 cubic yards	14.65	2,930	
Pipes and weirs			275	
Distribution channel			105	
				5,750
Sludge beds	1,400 square feet	.18	252	25[illegible]
Outfall	300 feet	1.85	555	55[illegible]
Land	1 acre		2,500	2,500
Road and right of way				60[illegible]
Total main plant				$38,1[illegible]
Disinfection Evershed tank				50[illegible]
				38,6[illegible]
Fixed charges at 6 per cent				2,3[illegible]

ACKNOWLEDGMENT.

Data for this report has been secured through the courtesy of Mr. J. Rattray Wilson, consulting engineer, and of Mr. A. P. Smith, village engineer. Mr. Fred Brooks and Mr. E. A. Arnold, respectively, president and clerk of the village, have also furnished information.

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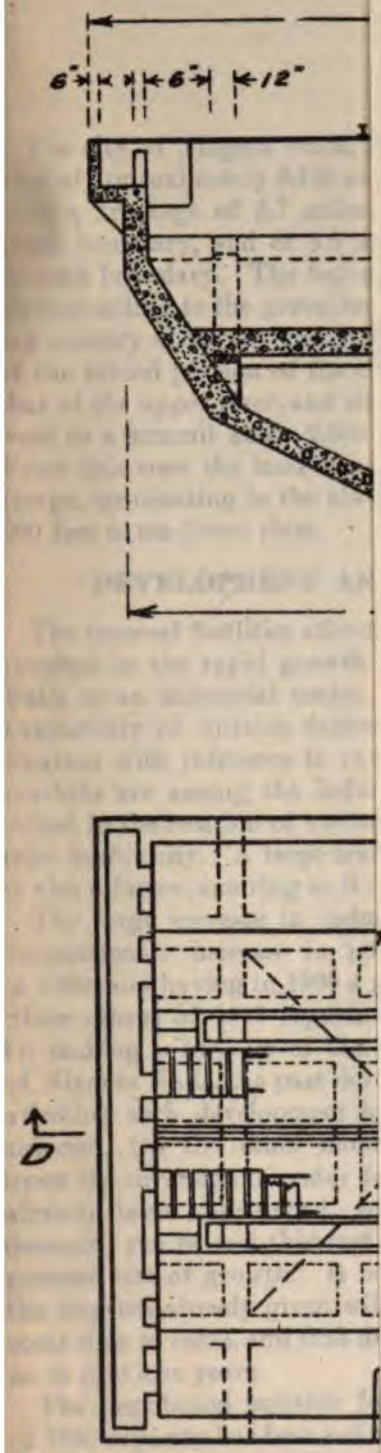
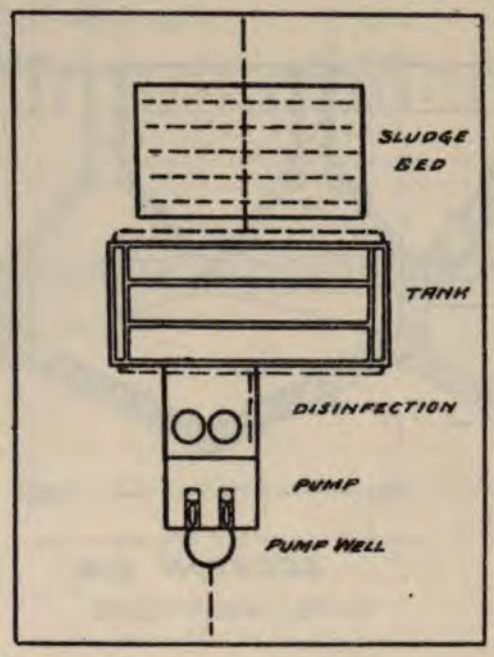
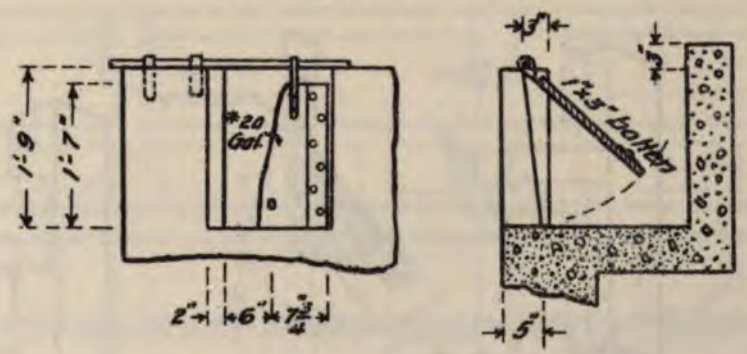


TANK CAPACITY
0.54 c.f.s. overage
Settling 4670 c.f.
Storage 3500 c.f.



SKETCH LAYOUT



WEIR GATE

LA SALLE, N.Y.
IMHOFF TANK STUDY

SCALES
Plan and Sections 8 ft.
Details 1 ft.

1915

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per second, which is equivalent to a run-off of 0.56 inch per hour from the present drainage area. With the rapid development of territory to the east and north, a further burden will be placed on this sewer unless some relief is provided.

As bearing upon the disposal problem from an economic standpoint, the suggestion is offered that relief could be afforded by a similar trunk sewer in Ashland Avenue, with present terminus at Twenty-second Street. This trunk would pick up the 60-inch lateral at Twenty-second Street and all laterals east thereof which flow south to the present trunk. As the districts to the east develop, the tunnel should be extended to provide drainage for this territory. It is believed that this construction would insure immediate relief, and in addition provide for all future demands within the limits of economic forecast. To satisfactorily pass present dry-weather flow, and to provide future maximum capacity, this and similar sewers should be provided with invert lining.

No detailed estimate has been made on this project, as it has no direct bearing upon the present study except in so far as it affects the cost of ultimate collection of city sewage. Such construction would, however, bring the sewage from this district direct to the site selected as suitable for disposal, and thus reduce considerably the cost of collection. It is roughly estimated that the construction cost would not exceed $150,000 as at present needed.

It is assumed that if relief is necessary in other sections of the city, such relief will take the form of reconstruction along the general course of the present sewers, and will in no way affect the manner or point of collection.

WATER CONSUMPTION.

The Niagara Falls water supply is furnished by two rival companies, the municipal plant and the Western New York Water Co., both of which filter and disinfect the raw supply. The private corporation has 30 miles of mains and generally supplies to consumers in the south end of the city, to a majority of the hotels, and probably exclusively to industrial plants south of Buffalo Avenue. The supply is entirely metered.

The municipal plant has approximately 140 miles of mains distributed throughout the city. In the southern section the city mains parallel those of the private corporation and supply to a majority of the private consumers. But a small percentage of the supply is metered, water being furnished on a flat rate.

During the year 1914 the Western New York Water Co. pumped to its system an average of 6,200,000 gallons daily, of which 1,250,000 gallons, or 20 per cent of the total supply, were unaccounted for. Of the water consumed, 60 per cent, or 3,000,000 gallons per day, was for industrial purposes, including 1,200,000 gallons furnished to the railroads. A large percentage of the remainder was delivered to hotels in the commercial district, and to the New York State Reservation in lieu of riparian rights.

The average daily supply from the municipal plant during the same period amounted to 11,400,000 gallons per day, of which approximately 3,500,000 gallons were estimated to be lost in waste and leakage. The industrial supply amounted to about 1,700,000 gallons per day. Recent records show a tendency toward a reduction of consumption. This has been recognized in the leakage figure under sewage flow, and in a general decrease in the per capita rate for the future.

The records of water consumption were not studied in detail, but sufficient data were obtained from the two companies to allow of a reasonable estimate of variations in consumption. The data secured consisted of the total consumption for each month of the year 1914, the average daily rates for a full week during the months of June and December, and the hourly variations for a typical day.

The total monthly consumption figures show but slight seasonal variations, the maximum of 112 per cent of the average for the year occurring in February, and the minimum of 91 per cent occurring in November. From the data assembled it has been estimated that the probable maximum variation for any one day exclusive of days of extraordinary drain on the system by reason of fires, breaks in mains, etc., should not exceed 140 per cent of the average daily rate, and that the maximum daily variation for any one hour should not exceed 170 per cent of the average daily rate for the year. This ratio, while applicable to the total consumption, is not indicative of variations in any subdivision of the total, and has been used as a check to other estimates.

It is probable that the variations as indicated by the meter records do not show the actual variation of consumption, but are affected by the high rate of leakage, which is not constant, and which probably reaches a maximum in the absence of other drafts upon the supply. It is considered, however, that the figures are indicative of sewage flow conditions.

SEWAGE FLOW AND SEWAGE UNITS.

A comprehensive survey of the city was made at the beginning of the work, in order to determine the extent of industrial and commercial development. It was found that about 390 acres of land were entirely devoted to intense manufacturing development at the time and about 80 acres to commercial purposes of a varied character. These figures were projected to rough 1950 values of 720 and 115 acres, respectively.

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A subdivision of water consumption into classification of usage is shown in Table 160. The percentage of each class listed as "returned as sewage" is the result of a canvass in the city of Buffalo of over 200 industries and other large consumers. The table shows a supply of 440 gallons per capita, of which 300 gallons per capita, or 68 per cent, is estimated to be returned as sewage. To establish values for the different units of maximum flow, measurements were made in three of the trunk sewers draining typical districts—residential, industrial, and commercial in character. These three districts were those discharging to the Twenty-second Street sewer from north of Niagara Street to the Twenty-second Street sewer from the south, and to the Riverway sewer. These gagings were taken at a period when ground water leakage was high, and it was necessary to deduct a certain amount from the total as derived from that source. It is recognized that, locally, infiltration is high, particularly in the unlined tunnel sections, and, therefore, a unit of 60,000 gallons per mile of sewer was assumed as reasonable. This figure, applied to 84 miles of sewers, draining some 2,670 acres, amounts to 1,890 gallons per acre daily. A unit of 2,000 gallons per acre per day was adopted, and was used in connection with the gagings. This amount is that shown as the infiltration unit in Table 160.

Estimates of population in each of these districts were also made from the 1915 unofficial State census returns. Inasmuch as readings were taken at odd hours, evaluations of maximum flows were effected by the application of variation curves from other cities.

In the Twenty-second Street sewer the maximum rate was thus estimated at 4.5 cubic feet per second, or 2.9 million gallons daily. The area above the point of gaging is 660 acres, with a population estimated at 7,900 persons. The resulting maximum per capita flow was 200 gallons per day. Similar estimates on three other sewers of a residential character gave results of from 200 to 240 gallons per capita per day, leading to the adoption of a unit for these studies of 220 gallons per capita daily.

The sewer selected for the estimate of industrial flow drains territory which is truly representative of the intense industrial development at the Falls. The result here indicated an average maximum unit of 14,500 gallons per acre per day. The area above the point of measurment is 199 acres, that portion devoted exclusively to industrial purposes is 112 acres, and the estimated population 1,200 persons.

During 1914, the rate of industrial consumption, exclusive of railroad use of water, was approximately 3.5 million gallons daily, and as the total industrial area is 390 acres, the consumption was at the average rate of 9,000 gallons per acre per day. If 70 per cent of this be considered as discharged during the 10 working hours, this would amount to an average maximum rate of discharge of 15,000 gallons per acre per day. In order to allow for an unknown quantity of water pumped by industrial plants along the south shore, a unit of 15,500 gallons per acre per day has been adopted.

The major part of the commercial district discharges through the Riverway and the Niagara Street sewers. The total area of this district is about 204 acres, of which 70 acres are commercial in character. The resident population numbers 4,540. The average maximum rate of flow, as estimated from gagings corrected to maximum discharge, was 9.9 cubic feet per second, or 6,400,000 gallons per day. The resulting sewage unit for average maximum rate is 72,500 gallons per acre per day.

It is not claimed for these units that they are any more than rough approximations of true conditions, but in the short time available the attainment of any more definite was not feasible. A summary of these units has been combined with the subdivision of water consumption in Table 160 to permit of visual comparison.

TABLE 160.—*Water consumption and sewage flow, 1914, Niagara Falls, N. Y.*

Subdivision.	Water consumption.						Sewage flow.		
	Supplied.		Returned to sewers.					Maximum rate.[2]	
	Total M. G. D.[1]	Per capita.	Percentage.	Total M. G. D.	Per capita.	Total maximum rate, M. G. D.[2]	Unit.	Total M. G. D.	Per capita.
Leakage, 170 miles	4.2	105							
Railroads	1.2	30	25	0.3	7				
Industrial, 390 acres	3.5	88	95	3.3	83		15,500 G. A. D.	6.1	152
Commercial, 80 acres	3.0	75	100	3.0	75		72,500 G. A. D.	5.8	145
Domestic, 40,000 persons	5.7	142	95	5.4	135		220 G. C. D.	8.8	220
Infiltration, 2,670 acres							2,000 G. A. D.	5.3	133
Total consumption	17.6	440	68.2	12.0	300	20.4			
Total sewage								26.0	650

[1] M. G. D.=million gallons daily. [2] At 170 per cent of average daily rate for year. [3] From gagings; see text.

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The sewage-flow units of Table 160 applied to 1914 and to 1950 values of population and of development give rise to the total quantities shown in Table 161:

TABLE 161.- *Maximum sewage flow, present and future, Niagara Falls, N. Y.*

Subdivision.	Unit.	1914 M.G.D.	Future M.G.D.
Industrial	15,500 gallons per acre daily		
390 acres		6.1	
720 acres			11.2
Commercial	72,500 gallons per acre daily		
80 acres		5.8	
115 acres			8.4
Domestic	220 gallons per capita daily		
40,000		8.8	
100,000			22.0
Ground water	2,000 gallons per acre daily		
2,670 acres		5.3	
5,900 acres			11.8
	Total	26.0	53.4
	Gallons per capita per day	650	534

SITES FOR TREATMENT.

Before studying to any extent the detail features of an intercepting system of sewers, a thorough study was made of the city and adjacent territory for available disposal sites. Several of these offered, and comparative estimates were necessary to determine the most economical from the viewpoint of the interceptors needed. Because of the extreme depth of the larger trunk sewers, the location of treatment works within the plateau region would necessitate pumping against a considerable head either at the trunk sewers themselves if a surface collector were constructed, or at a main pumping station in the case of a tunnel collector. Consideration was also given to the feasibility of collecting the dry-weather flow from the lateral sewers at the entrance to the shafts of the tunnel sewers and conveying to a point of disposal. Neither proposition is within reasonable limits of cost; in the first case because of the cost of pumping, and in the second because both construction and operation charges are prohibitive.

The proposition of disposing of the city's sewage below the escarpment near Lewiston involves the construction of approximately six miles of tunnel, and in view of other possibilities would prove unreasonable in construction cost.

For study and estimate purposes, a site has been selected on the slope of the gorge side at the foot of Ashland Avenue, and running north thereof. The total width of the strip from the Gorge Route Railroad to the water's edge is approximately 300 feet and has a surface slope of about 40 degrees. This condition exists in both directions for a considerable distance, and offers the most economic site for the disposal of the city's sewage.

COLLECTION.

With this location in view, a study was determine the most economical means of with results as shown in plan on plate 54 a file on plate 55. The adopted project inclu nel collector driven through the rock from Street at Second Street to Ashland Avenue section 6½ by 6 feet, and lined with concrete and sides. This interceptor will convey t of the south territory to the treatment site. Riverway sewer at Niagara Street a divers is planned to deliver the sewage from this the south collector at Main and Niagar Cross sewers along the route of the collecto charge their dry-weather flow through drill-h to the interceptor.

From the Cleveland Avenue tunnel trun similar marginal tunnel collector is planne vey sewage from the northern area to th site, joining the south collector at Ashland a common extension to the point of final From Cleveland Avenue to Chasm Avenue t ern branch will be extended as a surface divert to the south the sewage of the Bath a Avenue districts.

The sewage from Garfield Avenue and fr Avenue it is proposed to convey to some point for separate treatment, the econom arate treatment being quite apparent in vi collector and pumping costs involved in carri main works.

The basis of interceptor design is shown 162. In the case of tunnel sewers econon struction sections were desired rather than herence to capacity requirements, but in the lined portion is designed to take a lit cess of the maximum rate of dry-weather the surface collectors capacity figures have hered to closely.

The location of the interceptors shown o is fixed within certain limits by existing out tions. The main portions of the tunnel s been tentatively located close to the face o with the purpose of facilitating constructi use of spoil disposing drifts to the cliff side.

In all cases it is proposed to divert to the i only the dry weather or sanitary flow. S will be accomplished in the tunnel sewers by the trunk sewer with its crest at a predeterm vation, depending on the amount to be diver interceptor, which will accept all diversio level. Excess storm flow will overtop the discharge through present outlets to the rive

Similar provision is made in the case o sewers which are tributary to the tunnel except that the diversion sewers will lead to

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manhole chamber over the interceptor with connection thereto through drill holes of a sufficient diameter to avoid clogging. This method of connecting high-level and low-level sewers is already in use in the city for discharging to tunnel outlets.

The northern surface collector from Chasm Avenue to Cleveland Avenue has been located in Whirlpool Street in order to intercept at a high level and at the same time to provide cover for the collector. In this instance it is thought that leaping weirs will prove most satisfactory as a means of diversion. These weirs should be adjustable and set so as to insure the diversion of the maximum rate of sanitary flow.

No great disadvantage will accrue as a result of excess flow in the tunnel collector in addition to that for which it is normally designed, as it is of sufficient section above the lined portion to care for considerably increased flow, and such excess as does find its way to the collector will only result in a slight reduction of treatment efficiency during storm periods. This reduction will not materially affect the ultimate end, as otherwise a large portion would discharge untreated into the river. For this reason, it has not been deemed necessary to provide regulators to the interceptor, for in addition to the constant attention required, their operation is more or less problematical.

TABLE 162.—*Maximum sewage discharge 1950, Niagara Falls, N. Y.*

District.	Population, estimated.	Area in acres.			Sewage flow, M. G. D.				Total maximum rate, sewage flow.	
		Future sewered.	Industrial.	Commercial.	Domestic, 220 G. C. D.	Ground water, 2,000 G. A. D.	Industrial, 15,500 G. A. D.	Commercial, 72,500 G. A. D.	M. G. D.	C. F. S.
Garfield Avenue	600	60	.....	.....	0.13	0.12	.....	.....	0.25	0.4
Lafayette Avenue	2,850	305	20	.....	.63	.61	0.31	.....	1.55	2.4
Maple Avenue	1,560	130	.....	.....	.34	.26	.....	.....	.60	.9
Chasm Avenue	6,400	475	50	.....	1.41	.95	.78	.....	3.14	4.9
Bath Avenue	4,200	150	14	.....	.92	.30	.22	.....	1.44	2.2
Cleveland Avenue	6,300	180	.....	15	1.39	.36	.....	1.09	2.84	4.4
Ashland Avenue	28,000	2,070	200	.....	6.16	4.14	3.10	.....	13.40	20.8
Walnut Avenue	4,000	100	26	.....	.88	.20	.40	.....	1.48	2.3
Niagara Street trunk	44,000	2,160	400	20	9.68	4.32	6.20	1.45	21.65	33.5
Riverway	8,000	200	10	80	1.76	.40	.16	5.80	8.12	12.6
Total	105,910	5,830	720	115	.....	.....	.....	.....	54.47	84.4

The Maple Avenue and Garfield Avenue collector is shown upon the plan, and is designed as a surface sewer to extend to a cliff side disposal site just north of the city limits. In order to avoid tunnel construction for this line, it will be necessary to install a small automatic pump similar in design to that shown on plate 49 for North Tonawanda. From the pump chamber the interceptor leads north in Whirlpool Street to the treatment site.

A branch of this north interceptor is planned to pick up the dry weather flow from the 54-inch trunk at Lafayette Avenue, where it now discharges down a shaft into the Garfield Avenue tunnel, and also from the 24-inch trunk in Garfield Avenue, conveying these flows at high level in the right of way to junction with the Maple Avenue branch.

INTERCEPTOR COST.

Estimates of cost for the collectors described have been prepared, and are given in Table 163.

TREATMENT.

The treatment studies at Niagara Falls, N. Y., have been confined to sedimentation processes as effected by two-story tanks of the Imhoff type, or by fine screens, and in each case supplemented by disinfection with a solution of commercial bleach.

As before described, the site selected as being the most suitable for the location of treatment works lies on the gorge slope at the outlet of the present Ashland Avenue sewer, and below the tracks of the Gorge Route Railroad. In considering the conditions attending the collection of sewage at the Falls, it is only logical that, if possible, treatment should be accomplished below the level of the city. Moreover, the Ashland Avenue site lies approximately half way between the far points of collection north and south, and offers sufficient area below the railroad for the location of the works. These, in brief, are the factors favoring the location suggested.

The objection to this location is its proximity to the Gorge Route Railroad and the attending effect upon tourists, but this antagonistic feeling is purely psychological, and tends to become less acute in the average mind with a realization of the importance of the subject.

The unusual conditions of this site seemed to warrant a more thorough study of the topography than was made in other cities on the American side, and accordingly a stadia survey was made of the gorge side from the face of the vertical cliff to the water's edge

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and for about 1,500 feet along the river. The topography is shown on the ground plan, plate 56. This area descends to the river at an inclination of from 40 to 42 degrees, and the solid rock foundation is covered with 4 to 6 feet of soil and talus, necessitating a clearing of the area, together with the cutting out of stepped footings.

TABLE 163.—*Cost of interceptor construction, Niagara Falls, N. Y.*

Location.	Size.	Length.	Approximate cost per lineal foot.	Total cost.
South end collection.	*Feet.*	*Feet.*		
Riverway diversion	2.5	600	$16.67	$10,000
South tunnel collector	6½ by 6	4,300	26.05	112,000
North tunnel collector	4½ by 6	3,100	22.60	70,000
Chasm Avenue surface interceptor	2 and 2½	2,600	7.78	20,200
Outfall to works	7 by 9	180	26.65	4,800
North end collection.				
Maple Avenue collector	1	4,100	5.22	21,400
Lafayette Avenue collector	1	1,200	7.17	8,600
Automatic pump				1,800
Connections				4,100
Total				252,900

SEDIMENTATION.

An outline of a plant for the treatment of the city's sewage by sedimentation, allied with disinfection, is shown on plate 56.

The plan consists in the main of coarse screens for the removal of the larger floating particles, grit chambers for the settling of the heavy inorganic solids, a disinfection plant where the commercial bleach is prepared and applied to the sewage, Emscher tanks for the sedimentation and digestion of the suspended organic matter, and sludge drying beds.

In the north end of the city will be a subsidiary and similar plant for the treatment of the sewage from the Maple and Garfield Avenue districts.

The plans and estimates for the treatment works are based on estimated future conditions as of 1930. These data are shown in Table 164.

TABLE 164.—*Sewage flow for treatment, 1930, Niagara Falls, N. Y.*

	1930 population.	Sewage quantity.			
		Average flow.		120 per cent average	120 per cent average
		M. G. D.	C. F. S.	M. G. D.	C. F. S.
Main works	66,300	24.7	38.2	29.6	45.9
North end works	2,700	.9	1.4	1.1	1.7
Total	69,000	25.6	39.6	30.7	47.6

SOUTH END PLANT.

The average rate of sewage flow is equivalent to 371 gallons per capita per day. The tanks have been designed to meet conditions estimated at 120 per cent of the above rate, or equivalent to about 446 gallons per capita per day. The grit and screen chambers are designed for ultimate conditions as of 1950 (see Table 162), these structures being of relatively small cost and of such nature that they can be most readily installed in full ultimate capacity at the present time.

In the study plans the flow elevation of the tanks, top tier, has been taken as 475, with the second and third tiers lower by 20 and 40 feet, respectively. These elevations provide for sufficient fall from the interceptor outfall for the operation of weirs for distribution.

COARSE SCREEN AND GRIT CHAMBERS.

The screen chambers as planned will be of somewhat wider section than the entering channel, with floor slightly above the invert of the entering channel. An overflow chamber at the side is designed to protect against flooding because of clogged screens. Upon the raised floor are placed the inclined screen frames carrying screen bars spaced 1½ to 2 inch centers. The overflow chamber is provided with vertical bars spaced on 4-inch centers. Cleaning will be accomplished with hand rakes and the screenings disposed of in an incinerator (see further Disposal of city refuse).

The grit chamber consists of four channels with a common inlet and outlet and so arranged that one or more can be cut off for cleaning or to enable adjustment of the flow-through velocity to that sufficient to settle out the maximum amount of mineral matter. Cleaning may be accomplished by shoveling the detritus into small hopper cars running on industrial tracks in the bed of the channel, or else a gravity hydraulic discharge can be devised. The plans include provision for hand cleaning and for a hoist and revolving crane for lifting the hopper cars. It is expected that the grit will be wasted or used to replenish sludge beds.

DISINFECTION PLANT.

To provide for a sufficient period for the action of the disinfectant upon the bacteria it is proposed to apply the bleach to the sewage prior to entrance to the tanks, and in such quantity as to give a proportion of five parts of available chlorine per million parts of sewage treated.

The disinfection house contains the necessary mixing apparatus, storage tanks for the prepared solution, space for chemical, and automatic dosing apparatus. Details of a typical plant as proposed here

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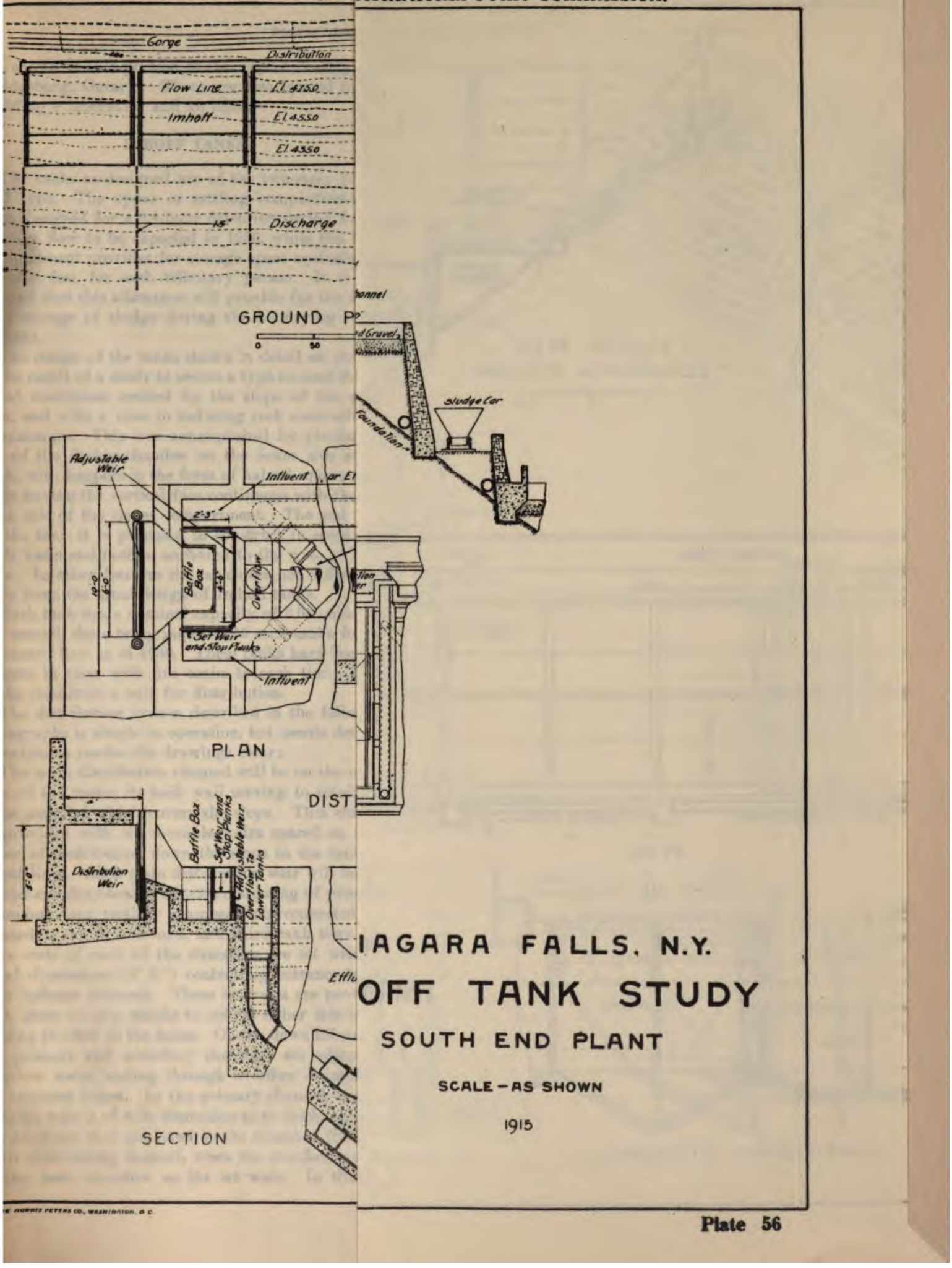

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The removal of the dried sludge is provided for by dividing the sludge beds into rows of three terraces each, there being three such rows. At the foot of the lower terrace of each group will be an industrial track of narrow gauge for operating hopper cars. A wooden chute at the end of each second bed will discharge the sludge to the cars on the industrial tracks. These tracks are connected to an incline operated by a small motor with cables for hauling the cars to the top of the bank, where the sludge will be transferred into cars on a spur track of the Gorge Route Railroad—the spur track it is proposed to use in conjunction with the city transit lines in conveying chemicals to the treatment site and for removing the dried sludge to some point of disposal.

Consideration was given to the proposition of pumping the wet sludge by compressed air to drying beds more suitably located from a construction standpoint. The only available sites were found to be distant 2 to 3 miles from the treatment works. The long pipe line necessary to convey the sludge to the beds, with the attending line losses for pumping to considerable distances, caused the abandonment of this scheme.

NORTH END PLANT.

The general works as planned are similar to those for the South End plant, with individual characteristics as noted.

The grit chamber consists of three channels provided with inclined screens of the bar type, similar to those designed for the Brighton plant at Rochester, N. Y. The screens will be cleaned by means of hand rakes. The detritus may be removed by flushing through valve-controlled cast-iron pipes below the floor and discharging on the slope below.

The sedimentation plant, consisting of one tank, corresponds in type to that for the main plant, but will be 84 feet long, with two flow-through chambers 8.5 feet wide, having a flow capacity of 1.7 cubic feet per second, which is 120 per cent of the average rate expected in 1930.

For conveying materials to the plant an elevator is provided on the face of the cliff. A small travel hoist, operating on a structural frame, will deliver chemicals from the elevator shaft to the disinfecting plant, while the dried sludge will be conveyed in cars on an inclined railway as at the major works.

The operation of this plant will require labor on the average of a few hours daily, and it is supposed that this will be supplied from the main plant.

SEDIMENTATION PLANT COSTS.

Estimates of cost of construction and operating have been prepared for both plants. The former are set forth in tabular form below, and are complete to the inclusion of royalty and engineering charges.

TABLE 165.—*Cost of construction, Imhoff tanks, South End plant, Niagara Falls, N. Y.*

Main item.	Subdivision of work.			Total cost.
	Amount.	Unit price.	Cost.	
Grit and coarse screen chamber.	Excavation, 3,100 cubic yards	$2.00	$6,200	
	Concrete, 103 cubic yards	12.60	1,298	
	Screen and fittings		787	
Disinfection plant	Buildings and channels, 10,000 cubic feet.	.26	2,600	
	Tanks, 86 cubic yards	14.00	1,204	
	Equipment		496	
Distribution system	Excavation, 880 cubic yards	2.00	1,760	
	Concrete, 530 cubic yards	12.00	6,360	
	Vitrified pipe		725	
	Appurtenances		590	
Imhoff tanks	Excavation, 1,050 cubic yards	2.00	2,100	
	Concrete, 455 cubic yards	15.10	6,871	
	Appurtenances		496	
	15 tanks at		9,467	
Sludge beds	Excavation, 9,820 cubic yards	1.08	10,606	
	Rubble, 1,400 cubic yards	4.05	5,670	
	Concrete, 1,255 cubic yards	8.60	10,793	
	Sand		1,500	
	Underdrain and piping		3,106	
Water supply				
Inclined railway				
Spur track				
Walks and steps				
Venturi meter				
Land				
Total				

TABLE 166.—*Cost of construction, Imhoff tanks, North End plant, Niagara Falls, N. Y.*

Main item.	Subdivision of work.			Total cost.
	Amount.	Unit price.	Cost.	
Grit and coarse screen chamber.	Excavation, 70 cubic yards	$2.20	$154	
	Concrete, 17 cubic yards	14.50	246	
	Screen, etc		150	
Disinfection plant	Building, 5,200 cubic feet	.32	1,664	
	Tanks, 27 cubic yards	13.60	367	
	Equipment		399	
Imhoff tanks	Excavation, 730 cubic yards	2.00	1,460	
	Concrete, 280 cubic yards	16.30	4,564	
	Appurtenances		876	
Sludge beds	2,700 persons	.482	1,300	
Water supply				
Inclined railway				
Elevator				
Walks and steps				
Land				
Total				

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FINE SCREENING.

The studies relating to fine screens have been confined to those of the Riensch-Wurl disk type, though without intention of excluding others from consideration. The sizes have been selected upon the Sanitary Corporation ratings in such proportion that with all units in operation the maximum diversion planned will be accepted with an overload on the screens of about 70 per cent. During periods of average dry-weather flow, with one screen out of commission, the balance of the plant will be overloaded to the extent of 10 per cent. Provision is also made in the screen house for one extra screen.

The long lines of rough-tunnel sewers and the frequent drops in the lines of the surface sewers at Niagara Falls causes the suspended solids to be considerably comminuted. Because of the resulting attrited condition of the raw sewage as it will reach the treatment plant, it is believed that a much smaller percentage of the suspended solids will be retained on the screens than is usual in other localities. Ratings have therefore been based on $\frac{1}{32}$-inch slots in the screen plates.

As in the case of sedimentation, the screen effluent will be treated with commercial bleach as a disinfectant, although the dose required will be somewhat larger than in the case of the tank effluent. It has been assumed that seven parts of available chlorine per million parts of sewage will suffice. To provide for the time needed for the action of the disinfectant, tanks or channels must be installed to allow of a 30-minute detention before discharging into the river waters, this period being based upon flows equivalent to 120 per cent of the average, which gives capacity sufficient to retain 1950 maximum flows for about 18 minutes. To further compensate for the attenuated character of the sewage and attending inefficiency of the fine screens, it is proposed to secure contact with the chemical in tanks of the two-story type, thus providing for additional reduction of the suspended solids.

An outline of the general plan for fine-screen treatment is shown on plate 57, together with a cross section detail of the detention tank. The plant consists of a combination grit and coarse screen chamber; fine screen house, disinfection plant, detention tanks, and sludge beds. No change has been made in the plans for treatment at the subsidiary plant.

GRIT AND COARSE SCREEN CHAMBER.

This chamber consists of three channels providing a reduction in velocity for the settlement of heavy inorganic matter. At the outlet end of the channels on a raised portion of the floor are set the coarse screen racks. The grit may be flushed through gate-controlled pipes discharging onto the slope below.

FINE SCREENS.

The screen house contains four 14-inch screens of the Riensch-Wurl revolving disk type, mounted in pits with structural frames, platforms, and operating equipment. An extra pit is provided for one future unit. The sewage enters and discharges from the screen pits through channels, the openings being controlled by gate valves. The retained solids are swept from the screen plates by brushes carried on a revolving spider frame, and are removed into containers which are taken from the house at intervals by means of a trolley hoist. It is proposed to burn the screenings in an incinerator.

DISINFECTION PLANT.

The disinfection plant will be similar to that described under tank treatment, though additional storage capacity will be required in the fine screen installation.

DETENTION TANKS.

A cross-section detail of the tank proposed for detention is shown on plate 57. This tank is to be 50 feet long with two sludge compartments. The detention period is to be 30 minutes, based on 120 per cent of the average flow as of 1930. Each tank has a capacity in the flow chambers of 14,000 cubic feet, equivalent to 7.8 cubic feet per second, thus rendering a total of six tanks necessary. The method of distribution to these tanks will be similar to that described under sedimentation. It is not possible to determine the percentage of reduction of suspended solids accomplished by fine screens combined with 30-minute sedimentation, except by experiment. It is thought, however, that this will be somewhat less than that obtainable by 2-hour sedimentation, and is offered as the minimum needed to accomplish the disinfection required, and at the same time secure a removal of organic matter comparable with that suggested for other riparian towns.

SLUDGE BEDS.

The sludge beds have been laid out on a basis of six persons per square foot, this amounting to one-half that required for Imhoff tank treatment. It is probable that this allowance is more than ample, but any reduction is not considered wise in view of the lack of data on the subject. Removal of the dried sludge is provided for in like manner to that described under the sedimentation process.

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FINE SCREEN PLANT COSTS.

The estimate of cost of construction of the above described plant is given in tabular form below:

TABLE 167.—*Cost of construction, fine screens, South End plant, Niagara Falls, N. Y.*

Main item.	Subdivision of work.			Total cost.
	Amount.	Unit price.	Cost.	
Grit and coarse screen chamber.	Decreased from Table 165			$7,200
Fine screens	Excavation, 3,300 cubic yards.	$2.00	$6,600	
	Substructure, 630 cubic yards.	12.35	7,780	
	Building, 3,200 square feet	.90	2,880	
	Screens, 4–14 foot	15,500.00	62,000	
	Appurtenances		740	
				80,000
Disinfection plant	Buildings, 10,200 cubic feet	.26	2,652	
	Tanks, 125 cubic yards	14.00	1,750	
	Equipment		498	
				4,900
Distribution system	Excavation, 300 cubic yards	3.40	1,020	
	Concrete, 455 cubic yards	13.00	5,915	
	Appurtenances		1,165	
				8,100
Detention tank	Excavation, 580 cubic yards	2.40	1,392	
	Concrete, 405 cubic yards	15.00	6,075	
	Appurtenances		366	
	6 units at		7,833	47,000
Sludge beds	One-half Imhoff tank allowance.			16,000
Water supply				1,200
Inclined railway				1,150
Spur track				3,500
Walks and steps				2,350
Venturi meter				2,200
Land				13,000
Total				186,600

OPERATION COSTS.

The estimated annual costs of plant operation, with subdivision thereof, are shown in Table 168. These costs are based upon common labor at $1.75 per eight-hour day, upon bleach at $25 per ton, and upon electric power at sliding rates according to published schedule. Provision has also been included for superintendence of the Imhoff tank plant at $1,800 per annum and for a mechanic superintendent for the screen plant at $1,315 per annum.

TABLE 168.—*Annual cost of operation, Imhoff tank plants, fine screen plant, Niagara Falls, N. Y.*

	Labor.	Materials.	Power.	Total.
South End Imhoff tank	$6,395	$14,472	$149	$21,016
North End Imhoff tank	540	526	75	1,141
South End fine screen	8,710	20,490	475	29,675
Total Imhoff tank	6,935	14,998	224	22,157
Total fine screen plant plus North End tank	9,250	21,016	550	30,816

POWER DEVELOPMENT FROM SEWAGE EFFLUENT.

The subject of sewage treatment can not be left without pointing out the possibilites of utilizing the effluent for the purpose of power development.

There is at present an average rate of sewage flow of 20 cubic feet per second available for this purpose. On the ground plan (plate 57) of the fine screen treatment project a small power house unit has been shown, though not included in the estimate, whereby a head of 110 feet can be obtained. Operating under a head of 110 feet, with a supply of 20 cubic feet per second, four units of Pelton impulse wheels would develop approximately 200 horsepower and would cost in the vicinity of $12,000 for complete installation, including supply line, Pelton wheels, automatic governors, and generators.

The operation of the disposal plant would require as a maximum but 20 horsepower, leaving the balance available for other purposes.

REFUSE DISPOSAL.

At the present time the mixed refuse of Niagara Falls is carted to a shaft over the Bath Avenue sewer and there flushed to the river at a point below Suspension Bridge.

The refuse thus disposed of consists of garbage, rubbish, and street sweepings. Some ashes are found in the mixed refuse, but the larger portion of ashes is disposed of separately. Brush, weeds, lawn rakings, etc., are dumped on a vacant lot near the plant and burned. All other forms of refuse are dumped indiscriminately into the river with the possible exception of bed springs and the like, too large to pass through the shaft.

Irrespective of the applicability of existing United States Federal Statutes,[1] there is no question but what other means of disposal of the city's refuse should be found and the present practice abolished. To this end, and in extension of the study of remedies for river pollution, there have been made rough estimates of the cost of an incinerator as the most satisfactory method of disposal and as further offering a means for the destruction of refuse from the sewage treatment works.

Records are kept of the number of loads delivered, the time of arrival, and the name of the driver. No record has been kept of volume or of weight of the refuse, but from personal observation combined with the data available, it is estimated that the average daily collections is about 75 to 80 cubic yards. This estimate does not include the ashes, which are disposed of separately.

An approximate classification of mixed refuse has been made from weighted averages of the per capita

[1] Revised Statutes of United States, Fifty-fifth Congress, third session, volume 2, chapter 425, section 13.

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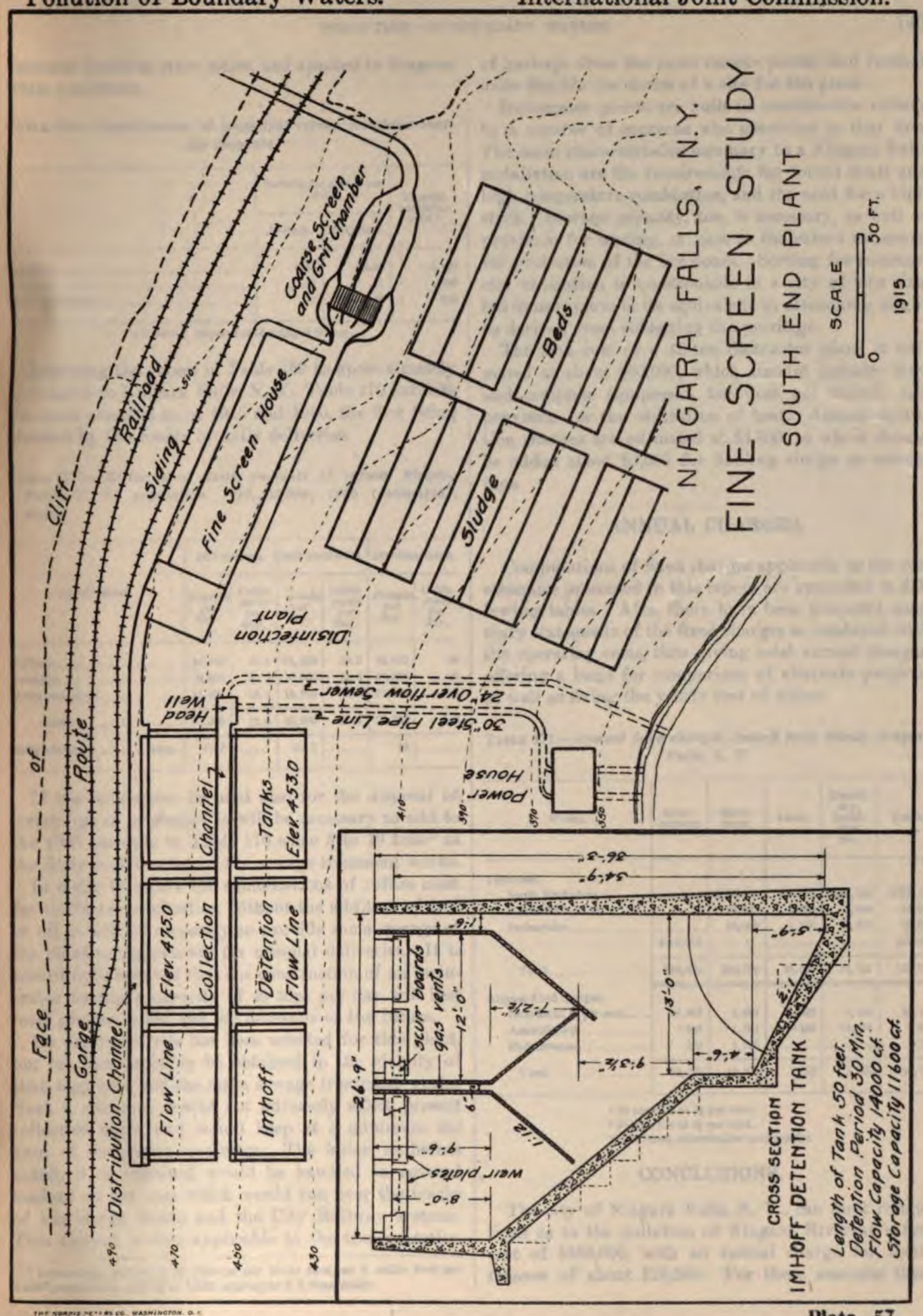

THE NORRIS PETERS CO., WASHINGTON, D. C.

Plate 57

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can be constructed and operated treatment works involving disinfection of the sewage and concomitant reduction of organic matter. Included also are all necessary sewers, together with an incinerator for the destruction of city refuse.

TABLE 172.—*Annual fixed charges, fine screen plant, Niagara Falls, N. Y.*

	Interceptors.	Structures.	Land.	Machinery.	Total.
First cost:					
Fine screen plant	.....	$108,616	$13,000	$69,984	$186,600
North End tank plant	.....	10,426	2,000	3,525	15,950
Incinerator	.....	10,000	1,500	18,500	30,000
	$252,900	.....	.....	.....	252,900
Total	252,900	124,041	16,500	92,009	485,450
Annual fixed charges:					
Interest at 4½ per cent	11,381	5,582	743	4,140	21,846
Amortization	[1] 346	[2] 694	[2] 93	[3] 9,201	10,334
Maintenance	300	620	.....	.....	920
Total	12,027	6,896	836	13,341	33,100

[1] 80-year life at 4½ per cent.
[2] 50-year life at 4½ per cent.
[3] Combined amortization and repairs at 10 per cent.

TABLE 173.—*Total annual charges, Imhoff tank and fine screen plants, Niagara Falls, N. Y.*

	Imhoff tanks.[1]		Fine screens.[2]	
	Total.	Per capita.[3]	Total.	Per capita.
Operation (Table 168)	$22,157	$0.321	$30,816	$0.447
Operation	6,300	.091	6,300	.091
Fixed (Tables 171, 172)	30,730	.445	33,100	.480
Total	59,187	.857	70,216	1.018

[1] Includes incinerator.
[2] Includes incinerator and North End tanks.
[3] 1930 population, 69,000.

ACKNOWLEDGMENT.

It is desired to acknowledge the cooperation and assistance of Mr. F. S. Parkhurst, jr., who was city engineer at the time these studies were made.

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NIAGARA FALLS, ONTARIO.

By H. S. PHILIPS, *Assistant Engineer.*

The city of Niagara Falls, Ontario, is located on the Niagara River, about one-fourth mile below the Horseshoe Falls. In addition to its character as a stopping point for tourists, the city is chiefly a hydro-electric power generating center, though containing but few important industries.

The corporate limits include about 1,630 acres and extend 2.7 miles along the river. The river frontage is well built up with residences, but the major development of the city is centered in the northwesterly section.

Topographically, the country is fairly hilly, with slopes toward the Niagara River. The soil is shallow, generally underlaid with solid rock from 2 to 5 feet below the surface.

POPULATION.

The growth of Niagara Falls in population is exhibited in Table 174.

TABLE 174.—*Population, Niagara Falls, Ontario.*

Year.	Population.	Decennial increase.	Annual increase.
		Per cent.	*Per cent.*
1871	1,610	.....	.....
1881	2,347	45.8	4.6
1891	3,349	42.6	4.3
1901	5,702	70.3	7.0
1911	9,004	57.9	5.8
1912	9,410	.....	4.5
1913	11,700	.....	24.4
1914	11,340	.....	[1] 3.1
1915	11,500	.....	1.4
1930	18,000	.....	3.8
1950	43,000	.....	7.8

[1] Decrease.

The figures for the period 1871 to 1901, inclusive, were obtained from census reports, while the balance were furnished by the city engineer and are noted as exclusive of hotel registrations of 200 and 700, for winter and summer, respectively.

The evidence of Table 174 gives force to the fact that this city is largely residential, and that presumably owing to the low cost of power transmission over Government-owned lines, Niagara Falls, Ontario, unlike the American city of the same name, has not proved attractive to power users, although retaining a possibility of future change in this respect. Forecast of population has accordingly proceeded along two lines, including for collector design an increase paralleling that of the American city and adjacent territory. For treatment works figures the past performance of this city together with percentage increases of Berlin, Guelph, and Brantford during corresponding periods of growth have led to a population for 1930 of 18,000.

Of influence in these determinations was the knowledge that any interceptor will be constructed partly in tunnel, where the size of section will be the minimum permissible for construction; and also by the fact that even with the population as fixed, the collector sizes will be moderate, and in any enlargement from needs fixed by the present rate of growth will allow for variation in development. On the other hand, the treatment works, standing for a smaller and by present standards more normal growth, can be readily enlarged as the need arises.

The distribution of population has been effected by subdivision into two main districts, being those of Bender Street, which includes the southern and eastern section adjacent to the Falls, and of the balance of the city, which is here denoted as the North End area. This subdivision as regards the future population follows the lines of present development, but lessens the existing preponderance. Table 175 presents the results.

TABLE 175.—*Subdivision of population, Niagara Falls, Ontario.*

Period.	Bender Street, 450 acres.[1]		North End, 645 acres.[1]		Total.
	Population.	Density per acre.	Population.	Density per acre.	
1915	3,060	6.8	8,440	13.1	11,500
1930 treatment	4,050	9.0	13,950	21.6	18,000
1950 interceptor	13,300	29.6	29,700	46.0	43,000

[1] Sewered areas.

The 1950 densities as computed from present-day drainage areas are greater than are warranted by the present characteristics of this city, but are intended to include provisions either for annexation of city area or for inland extensions of sewerage districts.

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Extensions along the river in either direction will have no influence upon sewerage suggested in this report. The distribution also locates the bulk of the population in that portion of the area to be served by interceptors.

WATER SUPPLY.

The city's water supply is taken from the Niagara River through an inshore intake a quarter mile above the Horseshoe Falls. The water is pumped direct to the mains, the existing reservoir being held for emergency use only. Treatment with liquid chlorine is but occasional as designed to meet any increase in pollution from that normal to the river at this point.

Water consumption records are available from the year 1896 to the present date, but until November, 1913, were based upon plunger displacement, and owing to breaks in counters and in other parts, the data are incomplete and unreliable. Detailed studies have, therefore, been confined to records since November, 1913, when a Venturi meter was installed. These records show a total pumpage of 1,287 million U. S. gallons during 1914, which is equivalent to a daily average of 3.53 million gallons, and to a per capita consumption of 307 gallons per day.

SEWAGE UNITS.

To convert the water consumption data into units of sewage flow it is necessary to take into account the variation in consumption and to provide capacity for seasonal, daily, and hourly fluctuations. A study of the water records with these ends in view establishes the following facts:

The consumption for the maximum month=116 per cent of the average monthly amount.

The consumption for the maximum day=110 per cent of the average daily amount.

The consumption for the maximum hour=125 per cent of the average hourly amount.

A synchronism of these maxima leads to a maximum maximum equivalent to 160 per cent of the average.

The water consumption figure of 307 gallons per capita daily may be expected to yield an average run-off of 95 per cent of this figure, or 292 gallons per capita per day, the balance being an estimate of that portion of the total supply lost in lawn and street sprinkling and in processes of manufacture. The particular expression of the ratio has been obtained from studies made in Buffalo as modified to meet local conditions.

The application of the maximum rate of flow of 160 per cent to the average rate of water consumption sewer discharge of 295 (292) gallons per capita daily gives a run-off of 467 gallons, or, as rounded off, 470 gallons per head per day, which is the figure that has been used for collector design.

No segregation of water-main leakage is pos
and no estimate of its amount has been made be
of a desire to retain a high run-off allowance a
only conforming to the present rate of consum
but as including a possible increase in industrial
sumption. Also many of the sewerage lines in
ara Falls are short, and in consequence require
peak capacities.

In addition to the sewage resulting from the
supply, the sewers must be proportioned to acco
date a certain amount of ground water infiltr
This leakage inward is certain in districts whicl
tain older sewers, and is unavoidable even whe
sewers are laid with due precautions and unde
best conditions. The amount varies with the cl
ter of the ground, rainfall, and the condition
drains. Numreous estimates and measuremen
daily leakage have been made in various cities
range from 20,000 to 100,000 gallons per day pe
of sewer. A figure of 40,000 gallons per mile of
has been assumed for Niagara Falls with due r
to the nature of the ground, as finding its way
sewers. This is equivalent to about 1,100 gallo
acre per day.

DRAINAGE.

For drainage purposes the city is at present di
into four districts, which are fairly well se
The outlets of each division are shown upon tl
companying sewerage map, and have capaciti
shown in Table 176.

TABLE 176.—*Existing sewer outlet capacities, Niagara
Ontario.*

| | Approximate drainage area (acres). | Ca
f
se |
|---|---|---|
| Bender Street | 450 | |
| Seneca Street | 162 | |
| Park Street | 333 | |
| Ferguson Street | 150 | |

A fifth outlet is planned to discharge at I
Street.

The system of sewerage is of the combined
carrying both domestic wastes and storm water
inasmuch as the prevailing sizes are small, the s
in some places are overloaded during heavy rain
though the outlets are, in all cases, sufficient to
the present and expected dry weather flow.

The sewers are on fairly good grades throughou
city, the limits not remote, and the sewage on rea
the treatment works should still be in fresh cond
with consequent absence of offensive odor.

TREATMENT SITES.

There being four existing outlets, it is feasil
treat the sewage at four different sites, or else to c

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Plate 38
SCALE
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tion of storm water to enter the intercepting sewer until the maximum capacity is reached. The admission of excessive amounts of storm water to the treatment works can be prevented at will by the regulation of storm overflow weirs at the works.

A statement of expected sewage flow quantities, and of resulting interceptor sizes, is given in Table 177.

TABLE 177.—*1950 sewage quantities, maximum—Sewer sizes—Niagara Falls, Ontario.*

District.	Total future drainage area, acres.[1]	1950 population.	Sewage (M. G. D.) at 470 G. C. D.	Infiltration (M. G. D.) at 1100 G. A. D.	Maximum sewage flow.		Accumulated sewage flow, C. F. S.	Interceptor.		
					M. G. D.	C. F. S.		Size (inches).	Grade.	Velocity (feet per second).
Bender Street	590	13,300	6.25	0.65	6.90	10.7	10.7	....	.....	....
Seneca Street	172	2,700	1.27	.19	1.46	2.3	2.3	15	0.0045	2.5
Muddy Run	230	5,500	2.59	.25	2.84	4.4	6.7	18	.0066	4
Park Street	330	13,600	6.40	.36	6.76	10.5	17.2	36	.001	2.5
Buttery Street	.....	.....	.....	.....	.....	.....	.....	20	.0238	7.5
Furgeson Street	290	7,900	3.71	.32	4.03	6.2	23.4	....	.....	....
Total	1,612	43,000	.....	....	21.99	34.1	....	....	.....	....

[1] The areas given here and in Table 178 represent estimates of tributary sewered area both inside and outside present corporations limits—They are not comparable to those in Table 175, nor do they total to the city area.

G. C. D.—Gallons per capita daily.
G. A. D.—Gallons per acre daily.
M. G. D.—Million gallons daily.
C. F. S.—Cubic feet per second.

TREATMENT.

Treatment-works studies have followed those outlined in the general report, with limitation to sedimentation and to fine screens, each coupled with disinfection by means of a solution of calcium hypochlorite.

In the case of tanks, the dimensions and proportions of the plants have been selected to give a sedimentation of two hours for an amount of sewage equivalent to 120 per cent of the average flow. These quantities as of 1930 are exhibited in Table 178.

TABLE 178.—*Sewage treatment quantities, Niagara Falls, Ontario.*

	Drainage area (acres).	1930 population.	Sewage (M. G. D.) at 295 G.C.D.	Infiltration (M. G. D.) at 1,100 G.A.D.	Average sewage flow, 1930.		120 per cent average flow, C. F. S.
					M.G.D.	C. F. S.	
Bender Street	490	4,050	1.20	0.54	1.74	2.7	3.2
North End	772	13,950	4.12	.85	4.97	7.7	9.2

Consideration of fine screens has been restricted to an installation for the North End plant because of the small flow to be treated at the southern plant. At the major works the 1930 average flow has been fixed at 7.7 cubic feet per second with a possible maximum of 23.4 cubic feet per second as the storm capacity of the interceptor. Upon commercial ratings, a 12-foot Riensch-Wurl screen having one-sixteenth inch slots is capable of passing 9.3 cubic feet per second with a 2-inch loss of head. With two such screens the available capacity is 18.6 cubic feet per second, or 80 per cent of the maximum sewage flow. With one screen out of order, the second would accept the dry weather flow, but at time of storm would be working under an overload of 160 per cent unless some of the sewage were by-passed. It is probable that by speeding up and through additional loss of head, a single screen could pass maximum storm flows. The loss of head in itself is not of moment, but its value is indicative of the removal of suspended matter, as any increase in the velocity of flow through the screen plates can result only in a decrease in the percentage removal of solids, and in particular of those finer solids which make up the bulk of the putrescible content of sewage. The screen sizes indicated are not entirely satisfactory, but have been embodied in the estimate as the minimum and most economic permissible.

SEDIMENTATION.

The details of the two plants being similar, a general description will apply to both. As will appear from reference to the plans (plates 59 and 60), the features included consist of quieting well, grit and coarse screen chamber, disinfection plant, Imhoff tanks, and sludge-drying beds.

QUIETING WELLS.

Wells with baffles have been placed at the outlet of the vertical portion of the interceptor to reduce the velocity and turbulence of flow. The baffle is of the underflow type, designed to prevent deposits. The wells are also provided with adjustable weirs at the side to permit of by-passing any desired portion of the storm flow.

GRIT CHAMBERS.

The grit chambers have been designed to allow detention of the flow for 45 seconds with a velocity of 0.75 foot per second. Three channels have been used in the Bender Street chamber and four at the North End installation, which provides in each case a spare channel for emptying and cleaning without interference with the regular process of grit settlement.

The detritus pit is hopper shaped and provided with a false bottom of wooden slats 1 inch apart, hinged at one end so that they can be raised or lowered to vary the channel cross section and velocity as desired. The sand collected can be used for replenishing the sludge-drying beds and arrangements could be made for a gravity discharge from the pit.

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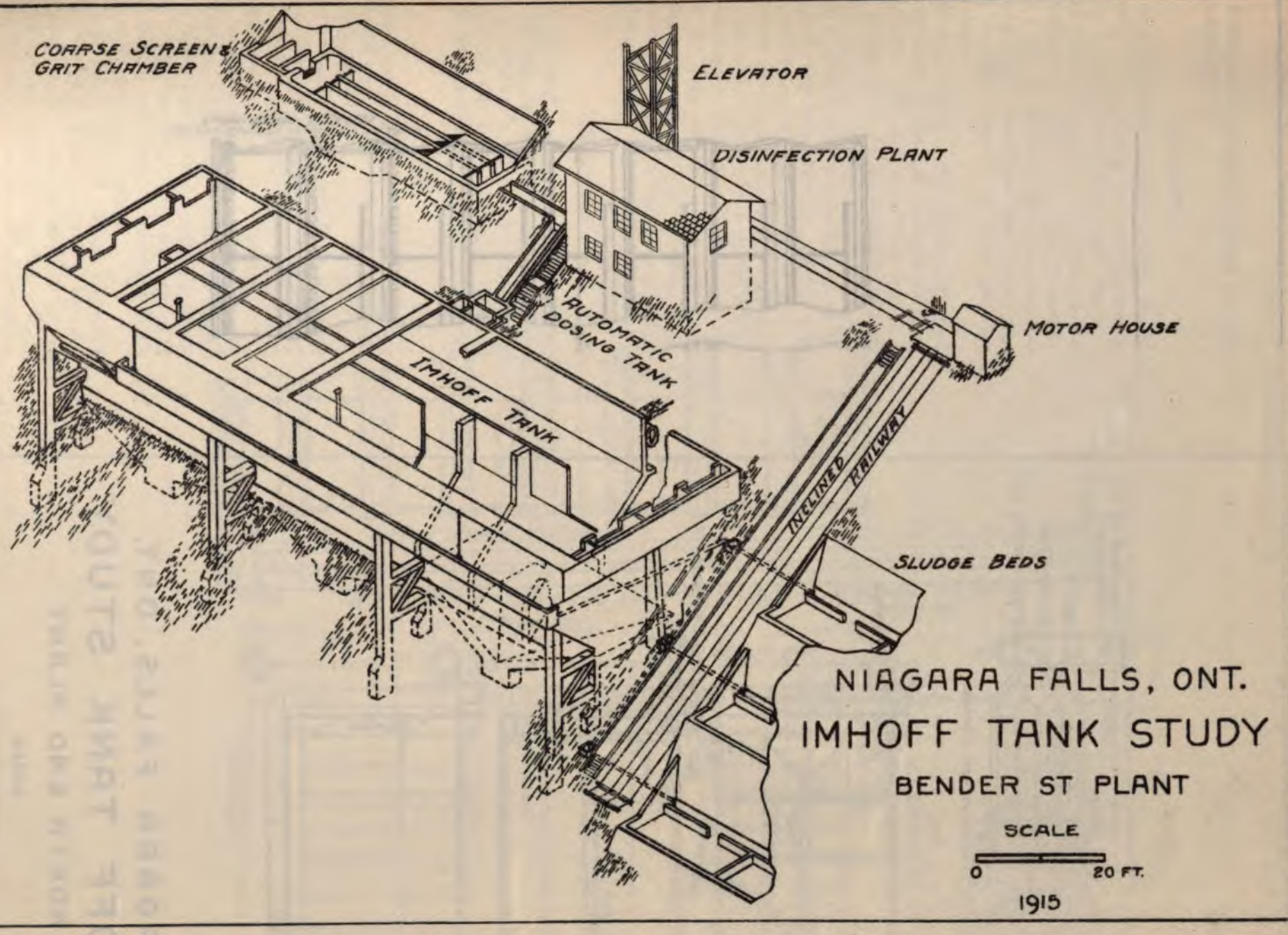

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DISINFECTION.

As shown in plate 61, the disinfection process is placed subsequent to the screens, the screen effluent with its charge of chemical flowing to a series of channels arranged in steps upon the hillside. These channels are such length as to secure a detention of 15 minutes at the time of maximum flow, and of such cross section as to maintain for average flows a velocity of about 0.7 foot per second without regulation of outlet gates. The desiderata in this case are a contact period adequate for the disinfecting action of the chemical, and a velocity sufficient to prevent deposition of solids; the latter is upon the theory that if the organic removal effected by screens is satisfactory, there is no warrant in adding to the expense of maintenance by securing additional removal of solid contents.

The disinfectant will be added in the proportion of seven parts of available chlorine per million of sewage, equivalent normally to 175 pounds of bleach per million gallons.

COSTS.

The construction and maintenance costs of the different features of treatment as herein presented have been prepared in accordance with contract prices prevailing in Niagara Falls. For machinery and similar fabricated work, American prices plus customs duties have been used. Labor has been estimated at $2.05 per day, and power to the small extent needed at 4 cents per kilowatt hour. The following tables are in summary of the detailed computations:

TABLE 179.—*Construction cost of interceptor, Niagara Falls, Ontario.*

Item.	Unit price.	Total.
3,025 cubic yards earth excavation	$0.80	$2,420
4,720 cubic yards rock excavation	3.50	16,520
2,100 lineal feet 15-inch vitrified pipe	.50	1,050
850 lineal feet 18-inch vitrified pipe	.72	612
775 lineal feet 20-inch vitrified pipe	.83	643
515 cubic yards brick masonry	10.00	5,150
232 vertical feet brick manhole	5.00	1,160
60 lineal feet 16-inch cast-iron pipe	2.65	159
		27,714
Engineering and contingencies	[1] 25	6,886
Total		34,600

[1] Per cent.

TABLE 180.—*Construction cost of Imhoff tanks, Bender plant, Niagara Falls, Ontario.*

Item.	Quantity.	Unit price.	Cost.
Clearing site			
Grit chamber and coarse screens:			
Excavation	178 c. y.	$2.00	$356
Concrete	53 c. y.	12.00	636
Screen and miscellaneous			91
Disinfection plant:			
Excavation	64 c. y.	2.00	128
Masonry	60 c. y.	10.00	600
House and machinery	4,200 c. f.	.25	1,050
Distribution system			
Imhoff tank:			
Excavation	800 c. y.	2.00	1,600
Concrete	400 c. y.	13.50	5,400
Sludge pipe, water supply, weir			500
Sludge beds:			
Excavation and rubble walls	50 c. y.	10.00	500
Concrete	45 c. y.	10.00	450
Sand, underdrain and piping			312
Inclined railway			
Elevator and motor			
Steps, water main, tool house			
Total			

TABLE 181.—*Construction cost of Imhoff tanks, North plant, Niagara Falls, Ontario.*

Item.	Quantity.	Unit price.	Cost.
Grit chamber and coarse screen:			
Excavation	300 c. y.	$2.00	$600
Concrete	87 c. y.	12.00	1,044
Screen and miscellaneous			196
Disinfection plant:			
Excavation	75 c. y.	2.00	150
Masonry	75 c. y.	10.00	750
House and machinery			1,050
Distribution system			
Imhoff tanks:			
From Bender Street estimate	28,600 c. f.	.25	7,150
3 tanks		7,150.00	
Sludge beds: From Bender Street estimate.	14,000 persons.	.31	
Inclined railway			
Elevator			
Steps, water main, tool house, etc.			
Total			

The operation charges for the sedimentation p are computed in the aggregate upon the assump that labor will be detailed from the major plant t smaller as needed.

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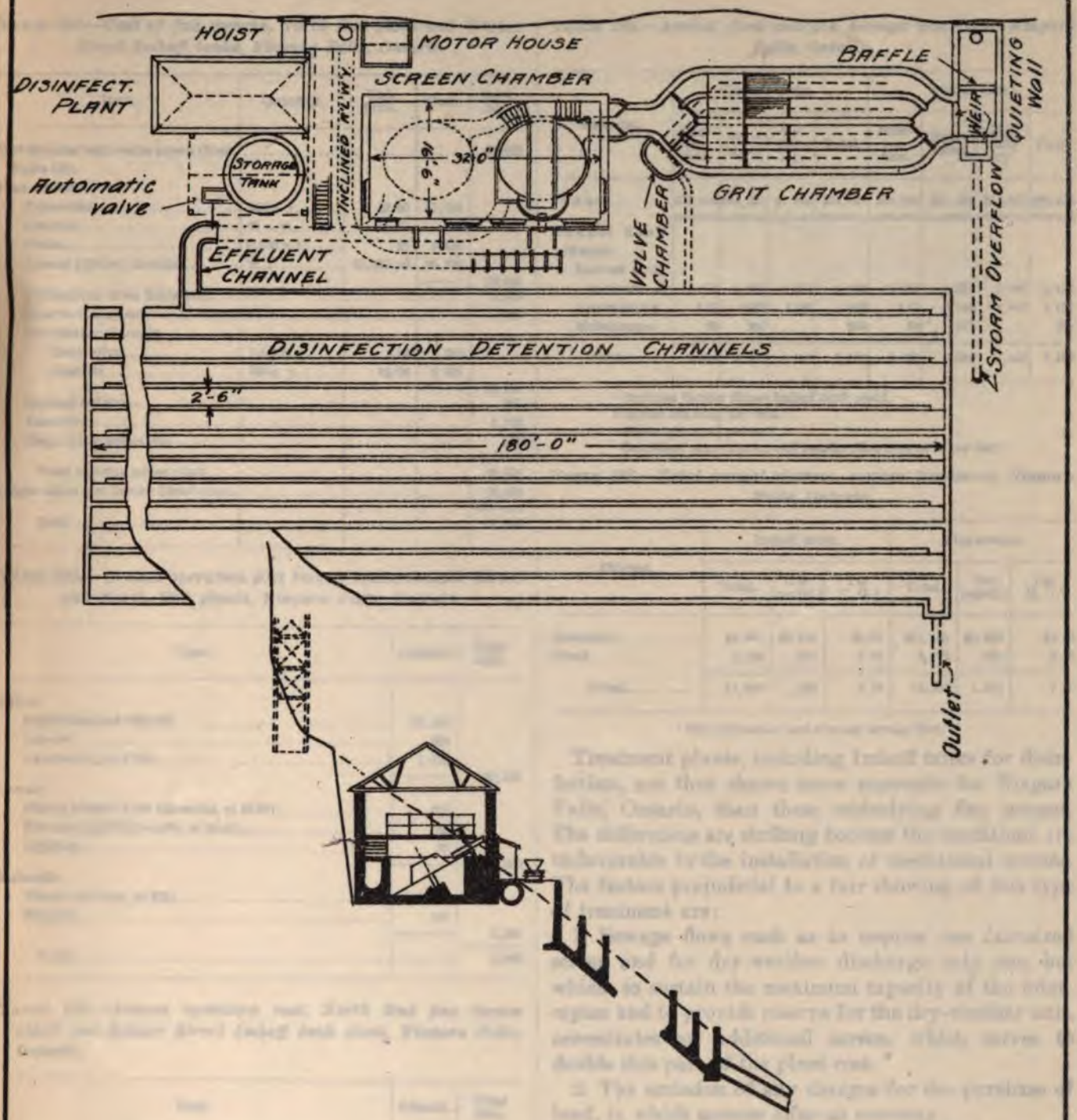

Plate 61

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only will the screens be overburdened during storm flows, but also at times of dry-weather flow the labor costs include provision for but 16 or 18 hours' operation, upon the questionable hypothesis that the very low night flows can be neglected. In this respect the tank plants possess an advantage in the manner with which they can be left without attendance, though still in operation.

CONCLUSIONS.

The finding of this report is to the effect that the city of Niagara Falls, Ontario, can meet restriction upon the river discharge of crude sewage by t struction of Imhoff tank and disinfection tre works at a first cost of $83,600 or less, and with labor and material charges of about $9,000.

ACKNOWLEDGMENT.

It is desired to acknowledge the aid freely e to the engineers of the Commission by Mr. F. derson, B. A. Sc., city engineer, who has supp data upon which these studies were based.

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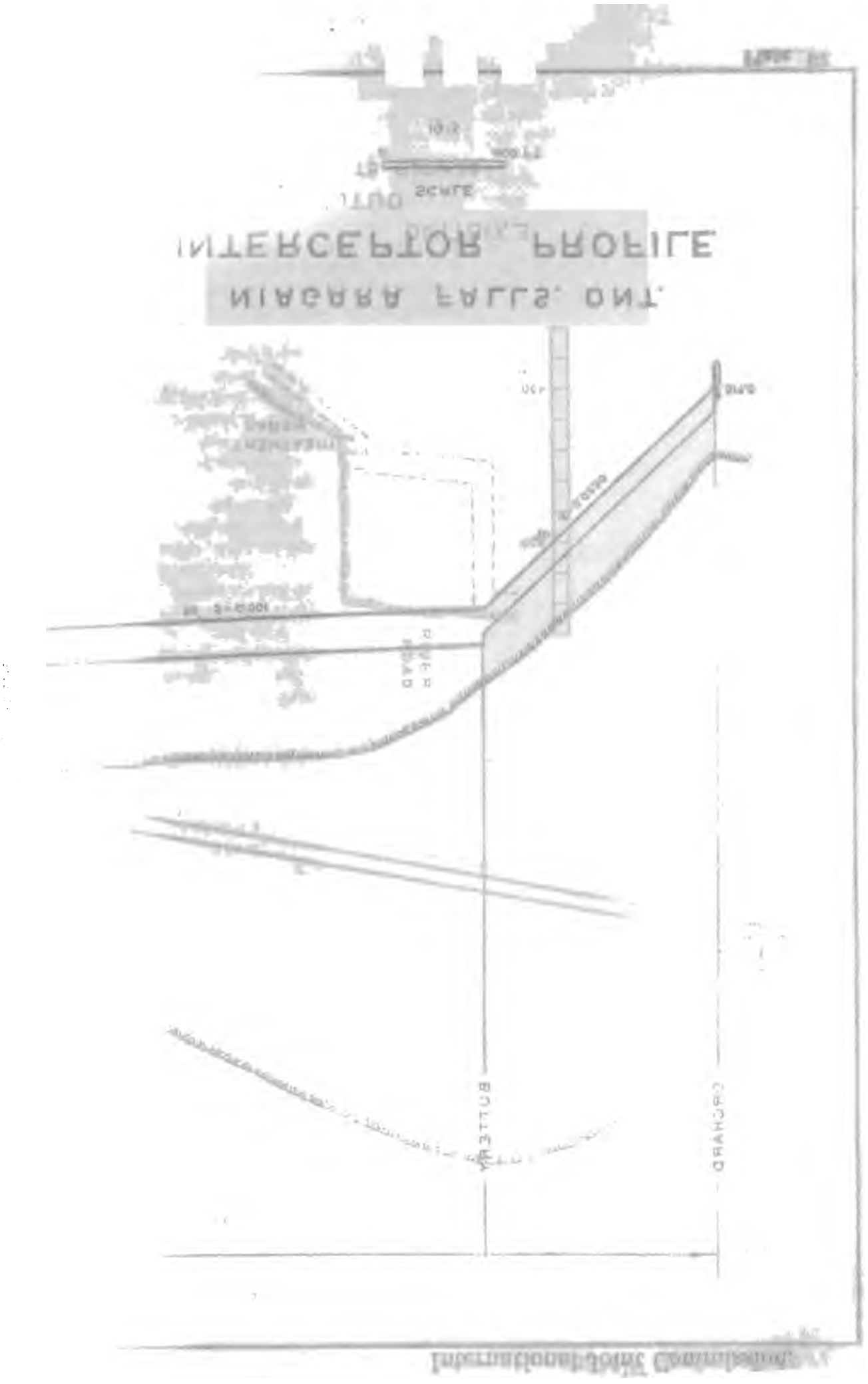

in the amount of chemical needed. It is further believed that the city can well afford the expense for the services of a competent chemist manager for a short time to establish an effective working regimen and to instruct plant operatives. The result of such procedure would justify the expense by ultimate economy of operation and relief of nuisance in Smokes Creek.

STEEL COMPANY SEWERAGE.

The balance of the city proper, which includes the steel company property known as Ridge Road village, is provided with sanitary sewers leading to treatment works of the nature shown on plate 64. This plant was designed by the City Wastes Disposal Co. of New York, and built by company forces in 1903, at a cost of about $20,000, of which $13,000 is applicable to the disposal works. Designed to receive the sewage of 3,000 persons to the extent of 300,000 gallons average daily flow, one unit of the settling tank now receives some 80,000 gallons daily and is of size sufficient to provide about 12 hours' storage while the pump well capacity holds about 3½ hours' flow, providing with float-operated pump average detention for half this period. The contact beds cover 0.125 acre, and with all beds in use receive a dose equivalent to 128,000 gallons per acre per day per foot of depth.

The effluent from both tank and beds indicates a considerable removal of organic matter, while both construction and operation of the works exhibit intelligent appreciation of the function and capability of the plant, being in pleasing contrast to the major city works.

The effluent from the beds discharges through 3,100 feet of sewer to a slip of the steel company canal extension of Buffalo Harbor, and inasmuch as the duration of flow in the discharge line is not less than 30 minutes its upper end offers a favorable point for the application of bleach solution. As in the case of Bridgeburg, for which town the installation is described in detail, the first cost of a disinfection plant would be $2,000 at a maximum. With the small flow and with a dose of five parts per million the cost of chemical would not be large, depending upon the economy of application. The cost of chemical for a flow of 80,000 gallons daily at a dose of five parts per million with chemical in small lots at $40 per ton would amount to $73 per annum, but the application of such minute quantities is not practicable.

In addition to the sewage from the city proper there exists a certain but unknown amount of drainage from the steel company's works and office building. The sewage from these sources is mingled with the cooling water and other industrial wastes pumped from the company ship canal by local plant to the extent of 65 million gallons daily, which is additional to a gravity supply of 44 million gallons daily. The sewage is untreated and reaches Buffalo Harbor through the ship canal and a comprehensive drainage system. No examination has been made as to the possibility of connecting the strictly sewage discharge to the Ridge Road treatment works, but a logical extension of the application of remedies to boundary water pollution involves some such course as possibly feasible through the agency of an automatic pump, with perhaps sterilization by steam as an economic alternative. It should be observed that as a source of pollution the works drainage is quite as serious as either of the company villages.

CONCLUSION.

Both the city of Lackawanna and the Lackawanna Steel Co. in their handling of the local sewerage question have advanced materially beyond other towns in this vicinity. The existing treatment works effect a positive removal of solids in suspension, and may also secure some reduction of pathogenic bacteria, though as pointed out in the general report, such action is neither uniform nor reliable.

Conformity to the procedure suggested in the general report would involve the addition of disinfection plants at a cost of not more than $2,000 each with operation charges for chemical not to exceed $1,000 per annum in the case of the major works, and a considerably smaller amount for the Ridge Road plant. Also, there would be required means for collecting and treating the strictly domestic sewage of the steel plant.

Inasmuch as the remedies suggested are, though important, of supplementary nature and capable of quick installation, and inasmuch as the total sewage discharge is comparatively small, it is believed that further action in this case can be delayed pending decisive moves on the part of some of the larger towns. In the meantime, however, the city authorities, either through efforts of their own initiation or with the aid of the State board of health, can well devote attention to an improvement in the operation of the city plant.

ACKNOWLEDGMENT.

Data concerning the city of Lackawanna were obtained through the agency of Mr. Maxwell Briggs, at that time superintendent of public works. For the Lackawanna Steel Co., Mr. C. C. Conkling afforded valuable assistance in placing at the disposal of the Commission copies of the treatment works record plans and in furnishing data as to drainage and water consumption of the steel plant.

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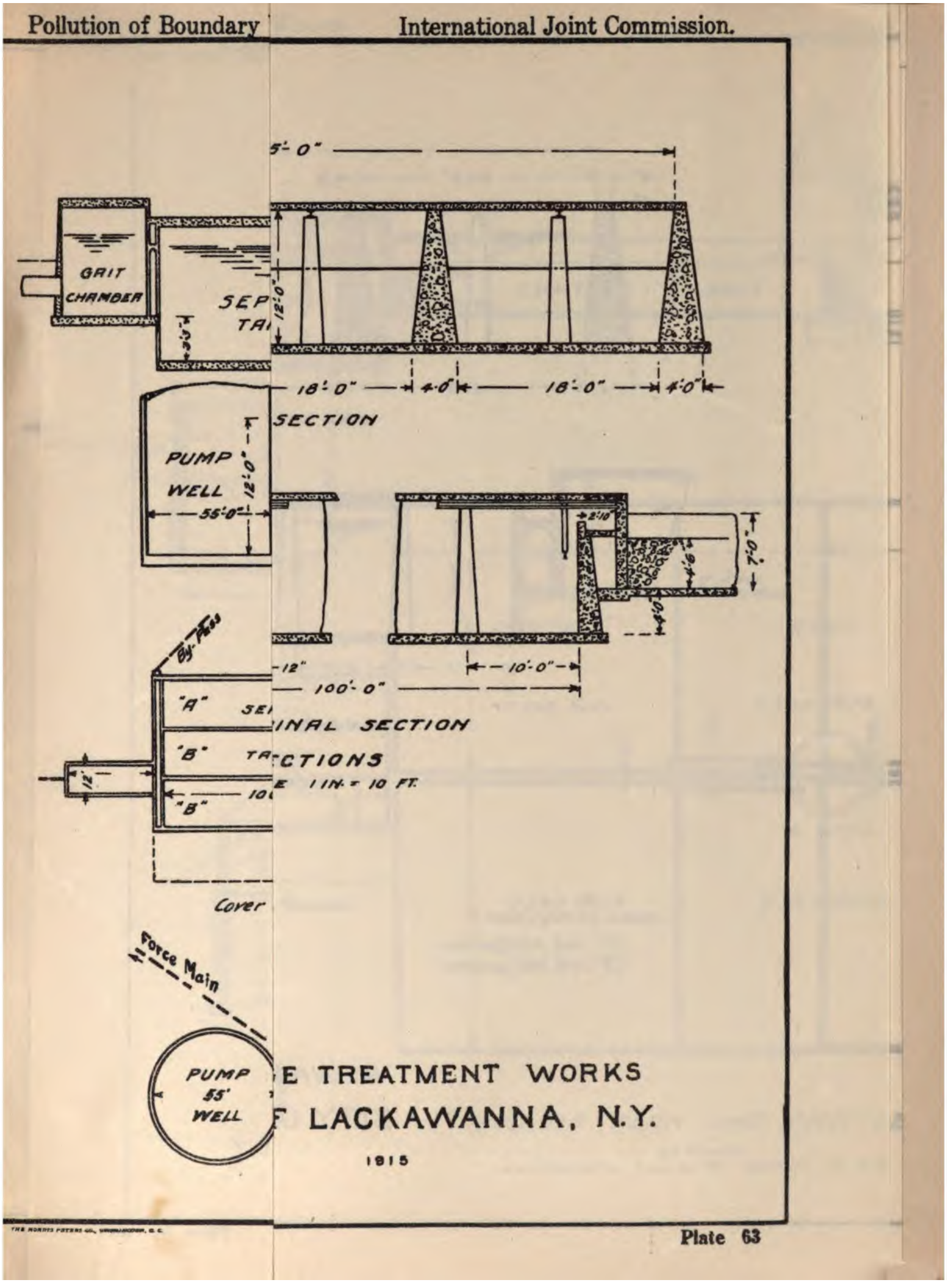

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land sufficient for the installation of settling tanks and contact beds when treatment of sewage becomes necessary. No estimates of the cost of treatment works have been submitted beyond that covered by the item for coarse screens.

When recourse to sewage treatment is had it is believed that this village will find it preferable to substitute Imhoff tanks and disinfection for the contact beds now in mind. This would not only accord with the sanitary needs of the river, but would effect economy in first cost and in annual charges. The plant construction in this instance should not exceed $4 per capita, which for a population of 2,500 would make a total of $10,000. Annual operating charges would probably approach $1,500, with fixed charges in the vicinity of $600.

CHIPPAWA, ONTARIO.

This is a small village of 700 people, situated on both banks of Welland River at its confluence with Niagara River. The community is essentially rural and obtains its water supply from wells, which fact leads to a local feeling that drainage of some kind is needed, for at present any sanitary drainage is limited to two or three private lines to the branch river.

Owing to the presence of the dividing river, sewage treatment for this community would be somewhat costly, involving the construction of parallel interceptors on the two banks, and, if duplicate treatment is to be avoided, requires a siphon from one side to the other. These factors, together with the scattering development, would probably entail the construction of 7,000 lineal feet of intercepting sewer, of which 2,500 feet on each side of the river is applicable to the collection, with 2,000 feet of outfall to a treatment site, which has been placed tentatively at the northerly edge of the village. With interceptor lengths as stated, and to treat the sewage from a population of 850, a rough first-cost estimate would run about as follows:

SEWER.	
7,000 lineal feet interceptor, at $3	$21,000
Extra for siphon crossing	2,000
1 automatic pump	800
TREATMENT.	
850 persons at $5	4,250
Total	28,050

Annual charges would be about $2,200, of which $520 are allowed for labor, material, and power.

QUEENSTON, ONTARIO.

Queenston, an undivided part of Niagara Township of the Province of Ontario, has a population of about 200, and is located on the Canadian side of the Niagara River immediately opposite to Lewiston. It is the terminus of the passenger line of boats plying between the Niagara River and Toronto, but otherwise is a strictly rural residential community, with small chance for increase in population unless there should occur a serious development of power at the rapids in the lower Niagara River.

Water supply is derived entirely from local springs and wells. Drainage is nonexistent, except perhaps in the case of two or three local residences which drain direct to the river. There appears no probability that this community will require the installation of sanitary drainage for some time to come, but should the need arise it would be quite simple to supplement any strictly drainage lines by the addition of some 1,000 feet of intercepting sewer which would serve to carry the dry-weather flow to any of several sites, the most convenient, perhaps, being in the vicinity of the lower reaches of the car loop of the electric line connecting to the Toronto boat landing, although this site has the disadvantage of being located somewhat upstream from the village itself, an objection which, considering the small amount of sewage which would have to be handled, and the large volume of the river, would not be of much force. The construction of interception of this character, together with supplementary tank treatment, would be covered by the following estimate of cost:

1,000 feet of interceptor, at $2.50	$2,500
Sewage treatment, 300 people, at $6	1,800
Total	4,300

As in the case of Lewiston, to which the community is in many ways similar, the operation costs should not exceed $500 per annum, with annual charges at 6 per cent of the construction cost.

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LEWISTON, N. Y.

The village of Lewiston, N. Y., with a 1915 population of 800, is located just north of the escarpment, at the head of navigation on the lower Niagara River. The area immediately abutting the river is utilized as a site for two summer hotels, and as the terminus of the Gorge Route Electric Railway. The village proper is located on the highlands, somewhat inland.

The water supply is derived entirely from local wells, although the village is now considering the installation of a pumping station and water mains, with the river as a source of supply. Of drainage there is none, cesspools and privies comprising the entire sanitary conveniences, except perhaps in the case of the two riparian hotels alluded to, which are reputed to discharge their wastes into the river. The construction of any sanitary drainage does not appear at all probable in the near future.

Field inspections, with a view to fixing the lines of ultimate drainage development, have been made, and the conclusion reached that the major village will be sewered into a trunk line running down the main street to the river, with perhaps short laterals in the River Road itself. For treatment, an attractive site is to be found on the river bank just north of the Gorge Route terminal loop, though others are feasible. Owing to the fall, available treatment works can be operated by gravity, needing only the construction of 800 feet of intercepting sewer as that additional to the strict drainage needs of the village. A rough estimate, involving such collector, with tank and disinfection treatment, would be as follows:

800 lineal feet of intercepting sewer, at $2.50	$2,000
Sewage treatment, 900 persons, at $4	3,600
Total	5,600

Operation, with proper economic use of chemical and with a part-time arrangement for the employment of labor, would probably reach in the vicinity of $500 per annum, while fixed charges would be $336 yearly.

YOUNGSTOWN, N. Y.

The village of Youngstown is situated on the right bank of Niagara River, adjacent to the mouth. It is a small farming community of 650 population, and serves as the center for a summer resident population.

The water supply is derived from the river, and with very slight sedimentation in a water tower is distributed in its raw condition. It is stated by Mr. Martin Primus, village president, that efforts have been made to install a mechanical filter, using alum as a coagulant, but that the plant constructed has been unable to meet the guaranty of 98 per cent bacterial removal. Consumption varies from 30,000 to 120,000 gallons daily, the latter figure representing a summer-time maximum.

The village is supplied with several storm drainage lines which discharge to the river. Generally the individual houses are provided with privies and cesspools, though some waste water and perhaps some cesspool overflows reach the river. In the case of the Union Public School situated in the village, the wastes are incinerated. Additional to the central village population there are a number of residences located along the shore road both north and south from the village proper, and it is quite probable that these either through cesspool overflows or directly discharge domestic wastes to the river. A number of small drains are to be found along the shore, and in some cases these have been laid by village permit; but inasmuch as the outlets are generally submerged, their exact function is obscure.

Field examination of the shore front and of the adjoining territory leads to the opinion that there exists in Youngstown no pressing need for sewage treatment. Should the future provision of sanitary drainage lead to a general discharge of municipal wastes correction of resulting river contamination would necessitate the construction of 1¼ miles of collector with suitable tank treatment, although due to its elevation above river level there would be no need for pumping. An exceedingly rough estimate of the resulting cost follows:

Sewer, 6,600 lineal feet interceptor, at $3	$19,800
Treatment, 1,000 persons, at $4.50	4,500
Total	24,300

The provision of 6,600 feet of collector really includes a certain allowance for local drainage that would be needed irrespective of the demand for treatment. In fact, the excess cost because of treatment should not go beyond $20,000 as a maximum. The annual cost for materials and labor would probably approximate $500.

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NIAGARA-ON-THE-LAKE, ONTARIO.

The municipality of Niagara-on-the-Lake is located at the mouth of the Niagara River, having frontage both on the river and on Lake Ontario. It is a summer residence center and is also the seat of the summer encampment of the Canadian militia. The population varies from a permanent figure of 1,400 to a summer residence of 1,900, the latter figure including the hotel registration.

Water supply is derived from the Niagara River, and is heavily chlorinated because of the extreme pollution existing in the river at this point. Water is used to the extent of 150,000 gallons during the winter season and 400,000 gallons in the summer. The community is sewered, with drainage through three outlets which extend into Lake Ontario for a considerable distance. In addition to these lines, the militia encampment discharges wash water into the Niagara River at a point close to the boat landing. The fecal wastes of the camp are removed from the kitchen sinks to inland points and there buried, thus obviating any effect upon Niagara River conditions.

The existing situation is probably one that does not directly concern the Commission, for while discharging its domestic wastes into Lake Ontario, which is a boundary water, it is far from probable that these wastes are able to cross the boundary, owing to the barrier interposed by the swift current and large body of the Niagara River. For this reason no very detailed study has been made of the local conditions, although it is believed that with the improvement of upper river conditions it would be proper and desirable for the corporation of Niagara-on-the-Lake to initiate improvements which would conform with those installed by superior communities, not only as a matter of equity, but also to protect the local bathing beach.

Sewage treatment, if installed, could probably be best handled in small individual tanks located at the several outlets which are separated some distance from each other, and are at such grade as to make perfectly possible the operation of the treatment plants by gravity. In brief, it is suggested that a proper interest in the improvement of the sanitary condition of the Niagara River district would lead the authorities of this town to construct at least small sedimentation tanks for the removal of organic matter. The cost of such installation would not be large, although estimates have not been made for the reason as stated, that this community does not properly present a problem to the Commission.

FORT NIAGARA, N. Y.

Fort Niagara is a United States military reservation situated at the intersection of the Niagara River and Lake Ontario. When fully garrisoned it accommodates some 300, although at the present time the population is less than this number. Water supply is derived from the river, is treated, and the drainage, both storm and sanitary, goes through separate lines to the lake.

This military post falls into the same category as its neighbor, Niagara-on-the-Lake, sewage treatment not being demanded as a remedy of conditions inhibited by the treaty, although, as in the case of Niagara-on-the-Lake, an improvement of upriver conditions should be followed by some local installation designed to fit in with the general scheme, and to insure protection against the pollution of littoral waters which may reach the bathing beach situated between the fort and Olcott, several miles distant on the lake.

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FINAL REPORT

OF THE

International Joint Commission

On the

Pollution of Boundary Waters Reference

▽

Washington–Ottawa

WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

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INTERNATIONAL JOINT COMMISSION.

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OBADIAH GARDNER, Chairman.	CHARLES A. MAGRATH, Chairman.
JAMES A. TAWNEY.	HENRY A. POWELL, K. C.
R. B. GLENN.	P. B. MIGNAULT, K. C.
Whitehead Kluttz, *Secretary.*	Lawrence J. Burpee, *Secretary.*

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LETTER OF TRANSMITTAL.

SEPTEMBER 10, 1918.

SIR: We have the honor to inclose herewith the Final Report of the International Joint Commission in the matter of the reference of August 1, 1912, submitted by the Governments of the United States and of the Dominion of Canada, under the provisions of Article IX of the treaty of January 11, 1909, between the United States and Great Britain.

We have the honor to be, sir, your obedient servants,

WHITEHEAD KLUTTZ,
LAWRENCE J. BURPEE,
Secretaries.

The honorable the SECRETARY OF STATE,
Washington, D. C.

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FINAL REPORT OF THE INTERNATIONAL JOINT COMMISSION IN THE MATTER OF THE REFERENCE BY THE UNITED STATES AND THE DOMINION OF CANADA RELATIVE TO THE POLLUTION OF BOUNDARY WATERS.

I.—INTRODUCTION.

Under the terms of Article IX of the treaty of January 11, 1909, between the United States and Great Britain, the following questions were submitted by the Governments of the United States and of the Dominion of Canada to the International Joint Commission under date of August 1, 1912, for examination and report upon the facts and circumstances connected with the pollution of boundary waters, and for such conclusions and recommendations as might be appropriate:

Original reference.

1. To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to the public health and unfit for domestic or other uses?

2. In what way or manner, whether by the construction and operation of suitable drainage canals or plants at convenient points or otherwise, is it possible and advisable to remedy or prevent the pollution of these waters, and by what means or arrangement can the proper construction or operation of remedial or preventive works, or a system or method of rendering these waters sanitary and suitable for domestic and other uses, be best secured and maintained in order to insure the adequate protection and development of all interests involved on both sides of the boundary and to fulfil the obligations undertaken in Article IV of the waterways treaty of January 11, 1909, between the United States and Great Britain, in which it is agreed that the waters therein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other?

Definition of boundary waters.

The expression "boundary waters" is used in the treaty with a special meaning, being therein defined as follows:

For the purposes of this treaty, boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms, and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers, and waterways, or waters flowing from such lakes, rivers, and waterways, or the waters of rivers flowing across the boundary.

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In this report the term "boundary waters" shall have the meaning attached to it by the treaty.

Amendment of reference.

The reference as thus submitted is broad enough to require an investigation of all boundary waters as the same are defined in the treaty without regard to the present or future transboundary effect of their pollution on either side; but when it first came before the commission at its Ottawa meeting in October, 1912, a doubt arose as to whether or not the two Governments intended that pollution in all boundary waters was to be included in the investigation, and a letter was addressed to both Governments requesting an expression of their views in such manner as they might deem proper—

> As to whether or not the broad scope of the inquiry is to be circumscribed by construction so as to confine the same to cases of pollution of the boundary waters upon one side of the boundary which may extend to and affect the boundary waters upon the other side.

By letter under date of November 19, 1912, the commission was informed by Mr. Knox, Secretary of State, that the Governments of the United States and Great Britain had—

> reached an accord that the inquiry is to be confined to cases of pollution of boundary waters on one side of the boundary which extend to and affect the boundary waters upon the other side.

The original submission as modified by this limitation constitutes the reference under which the commission is acting.

Omission of pollution in rivers crossing the boundary.

The treaty, in addition to prohibiting such pollution of boundary waters as would have the effect of injuring health or property on the side of the boundary line opposite to that in which it originates, prohibits the pollution of rivers flowing across the boundary line which has an injurious transboundary effect. The first question omits entirely any reference to pollution in these rivers, although it is involved in the second question submitted. The facts connected with pollution in rivers crossing the boundary line, however, call for no special investigation; and the commission regards it as clear that the treatment prescribed in the case of rivers which are boundary waters should be made applicable to them.

Interests and territory affected.

The reference has imposed upon the commission grave responsibilities. From the language of the submission and this prohibitory clause of the treaty, it is evident that the object which the two Governments had in view in making the reference was to see that their reciprocal obligations with respect to the pollution of those waters should be fulfilled. By the traditions of each country a treaty obligation is of supreme sanctity and is the highest law of the State. Any conclusions the commission may reach and any recommendations it may make, may, if acted upon, affect

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the physical health of millions of people who dwell along these waters, as well as the financial and other interests of eight States of the United States and three Provinces of the Dominion.

The people of both countries possess, in the splendid immensity of the series of waterways through which so much of their common boundary passes, a heritage of inestimable value. Millions of people dwell in their watersheds. Along the banks of the rivers and Great Lakes communities which a few years ago were mere villages are now in population, in social and industrial development, among the most important on the continent. Industries which have suddenly sprung up have an annual output of manufactured products aggregating in value $10,000,000,000. Agriculture and mining have kept pace with manufacturing in the line of expansion. According to official information the rural population of the watersheds cultivate to-day over 100,000,000 acres of land, and the yearly yield of the mines is valued at $300,000,000. The boundary waters are the natural channels of interstate and international commerce. The world possesses no other water thoroughfare comparable with the highway leading from the Gulf of St. Lawrence to the head of Lake Superior. While nature left comparatively little for man to do in adapting these waters to commercial needs, canals had to be constructed at certain points, and rivers, channels, and harbors deepened or created. These works involved an expenditure on the part of Canada of $250,000,000 and on the part of the United States of $135,000,000. Vessels drawing 19 or 20 feet can now navigate the Great Lakes from Duluth or Chicago to Buffalo. Some idea of the magnitude of commerce on these waters may be gleaned from the fact that the vessel passages up and down the Detroit River in 1916 amounted to 37,852, the registered tonnage of the vessels reaching 76,677,264, their passengers, including ferry passengers, numbering 15,000,000 and their freight exceeding 100,000,000 tons, valued at something over $1,000,000,000.

The Thousand Islands and hundreds of other attractive spots along the St. Lawrence River, the Great Lakes, and their connecting waterways, as well as in that splendid chain of boundary waters still farther west which lie within the Lake of the Woods watershed, afford unexcelled opportunities for rest, recreation, and pleasure, which are taken advantage of by a very large floating population during the summer months.

The directness of the water route from the Atlantic Ocean to the head of Lake Superior, the adaptation to water carriage of the freight borne by the lake boats, and the cheapness with which this freight can be transported by them, the completion of the barge canal from Buffalo to New York, the proposed enlargement of the Welland and other canals along the boundary rivers permitting the

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passage of vessels of 28 or 29 feet draft from the ocean to th heart of the continent, the future settlement of the great wheat bel of Canada, the fringe only of which has been touched, and the pos sible utilization of the 3,375,000 dependable horsepower of th boundary rivers, render the conclusion inevitable that the commerc and shipping on these waters and the wealth, the industries, and th population along their banks must in the near future reach dimen sions far exceeding their present attainment, and may ultimatel far surpass any area of similar extent in the world. In workin out the enormous possibilities of this vast section of the continer the proper observance of international sanitary requirements will b a most essential factor.

Scope of the inquiry.

The first branch of the reference expressly calls for an inquir into three subjects: (1) The location and extent the pollution of boundary waters, (2) the sourc from which this pollution is derived, and (3) th localities, if any, in which the pollution has a transboundary effe injurious to health or property. Involved in this last subject is th determination of what is an injury to health or property within th meaning of the reference and of the treaty. The second branch the reference calls for the recommendation of measures and metho for remedying or preventing existing or future evils.

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II.—PLAN OF PROCEDURE IN THE INVESTIGATION.

Examination of existing pollution.

While the answer to the question in the first branch of the reference covers chiefly matters of fact, the proper procedure to be followed in the investigations required the most careful consideration of everything involved, of the geographical and experimental limitations that might with advantage be imposed on the scope of the work, of the most suitable form of organization for carrying out the necessarily extensive examinations thoroughly, expeditiously, and economically, and of the minor details of technique and general procedure. Many of the matters involved called for expert assistance, and the commission enlisted the sympathetic aid and cooperation of sanitary experts, health officials, and others interested in both the United States and Canada in the preparation and carrying out of a plan of procedure. A conference was held at Buffalo on December 17, 1912, at which, on the invitation of the commission, the following officials and experts were present and participated: Mr. John Thompson, K. C., representing the Dominion Government; Dr. Frederick Montizambert, director general of public health for the Dominion of Canada; Dr. Charles A. Hodgetts, medical advisor, commission of conservation, Ottawa; Dr. John A. Amyot, director of laboratories, provincial board of health, Toronto; Dr. J. W. S. McCullough, chief health officer for Ontario; Mr. F. A. Dallyn, C. E., provincial sanitary engineer for the Province of Ontario; Mr. Theodore J. Lafrenière, sanitary engineer, provincial board of health of Quebec; Dr. Allan J. McLaughlin, United States Public Health Service, Washington; Hon. George Clinton, Buffalo; Mr. A. H. Seymour, secretary State department of health, Albany; Mr. Theodore Horton, chief engineer, State department of health, Albany; Dr. Edward Clark, medical health officer, State board of health, Buffalo; Mr. George H. Norton, deputy engineer commissioner, department of public works, Buffalo; Dr. Francis E. Fronczak, health commissioner, Buffalo; Mr. H. A. Whittaker, assistant director, laboratory division, Minnesota State Board of Health; Mr. John W. Hill, State board of health, Cincinnati, Ohio; Dr. Edward Bartow, director State water survey, Urbana, Ill.; Mr. W. M. Mills, president Niagara Frontier Pure Water Conference, North Tonawanda, N. Y.; Dr. W. G. Palmer, member of the Niagara Pure Water Conference, North Tonawanda; and Mr. Irving L. Pruyn,

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Oneonta, N. Y. Representatives from the health departments of Michigan, Wisconsin, and Pennsylvania, although requested to do so, were unable to attend.

The conference was organized, Mr. A. H. Seymour, secretary of the New York Department of Health, being appointed chairman, and Dr. Allen J. McLaughlin, of the United States Public Health Service, secretary.

The commission requested the advice of the conference as to the points in boundary waters where investigations should be made, the general nature of the investigations at these points, and other matters of detail.

The conclusion was reached that the points of investigation should include Rainy River, St. Marys River, Lake St. Clair, Detroit River, Niagara River, the St. Lawrence River from Lake Ontario to a point as far below the international boundary line as should be thought necessary, the lake waters in the vicinity of Port Arthur, Fort William, and Duluth, the lower end of Lake Huron in the vicinity of Sarnia and Port Huron, the western end of Lake Erie in the vicinity of Cleveland and Port Stanley, the eastern and western ends of Lake Ontario, and sections of the latter lake at Rochester and Toronto. It was contemplated that other points on the boundary outside of the Great Lakes system should be examined if subsequently deemed desirable.

The conference further advised the commission that the investigation should include a bacteriological examination of samples taken, including the bacterial count, the qualitative and quantitative estimation of *B. coli* according to standard methods, and such chemical examination as might subsequently be deemed necessary.

Bacteriological investigation.

In February, 1913, a detailed plan for conducting the investigation in its entirety was adopted, and Dr. Allan J. McLaughlin was employed as chief sanitary expert and director of field work. With him the commission associated Dr. J. W. S. McCullough, Dr. John A. Amyot, and Mr. F. A. Dallyn, C. E. For the sake of convenience these four gentlemen will hereinafter be referred to as "the sanitary experts."

The carrying out of the adopted plan involved what is probably the most extensive bacteriological examination of waters the world has ever known. It embraced Rainy River, parts of Rainy Lake, parts of Lake of the Woods, Thunder Bay in Lake Superior, St. Marys River, Mud Lake, Detour Passage, lower Lake Huron, St. Clair River, Lake St. Clair, Detroit River, the western end of Lake Erie, the central portion of Lake Erie, the eastern end of Lake Erie, Niagara River, the western and eastern portions of Lake Ontario, the St. Lawrence River from Lake Ontario to Cornwall, and the St. John River so far as it forms the international boundary. The num-

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ber of sampling points exceeded 1,500, and the number of samples collected at them was over 18,000. The following table shows the location of the laboratories, the waters examined, the dates of the examination, the number of sampling points, and the total number of samples:

Date.	Waterway.	Location of laboratories.	Number of sample points.	Total number samples.
1913.				
July 8–22	Rainy River	Fort Frances, Ont	192	955
July 28–August 15	Lake Superior (Thunder Bay).	Port Arthur, Ont	66	922
June 28–July 16	Lake Superior, St. Marys River.	Sault Ste. Marie, Mich	104	1,065
July 25–August 25	Lake Huron, St. Clair River.	Sarnia, Ont	142	1,606
September–October 10	Lake St. Clair, Detroit River	Windsor, Ont	174	1,755
September–October 3	Detroit River, Lake Erie	Amherstburg, Ont	114	1,306
October	Lake Erie, Port Stanley	Windsor, Ont	51	214
May 26–June 17	Lake Erie, Niagara River	Fort Erie, Ont	133	1,375
May 27–June 12	Niagara River	Niagara-on-the-Lake, Ont.	59	840
April 10–May 23	Lake Ontario, St. Lawrence River.	Kingston, Ont	113	928
May 23–August 27	St. Clair River, Lake St. Clair, Detroit River, Lake Erie.	Detroit, Mich	70	1,812
June 12–July 23	Lake Erie	U. S. revenue cutter "Morrill."	20	480
May 12–July 29	Lake Erie, Niagara River	Buffalo, N. Y	60	1,624
August	Lake Ontario, St. Lawrence River,	Clayton, N. Y	32	482
October	St. John River	Van Buren, Me	32	672
July 3–August 13	Lake Huron, Sr. Clair River.	Port Huron, Mich	45	720
August 1–August 21	Niagara River, Lake Ontario.	Youngstown, N. Y	42	338
August	St. Lawrence River	Montreal, Quebec	8	480

Points for the collection of samples were carefully located, but positions which might show exceptional pollution at sewer outlets were avoided, except in certain cases where information touching them was desired for special reasons. Owing to the extraordinary amount of navigation on these waters, fixed buoys were not feasible for the purposes of locating sample collection points and the work was carried on by a time and course method, the samples being collected at prescribed time intervals and along definite courses laid down on the charts of the waters. In swift-running water, as in the Niagara, Detroit, and St. Clair Rivers, diagonal courses were necessary in order to give some length to the cross sections and allow sufficient time intervals between the taking of the samples. The various field parties were all furnished with United States War Department maps showing a great deal of the topography of the areas under investigation, and also with copies of the sewer maps for the adjacent municipalities.

In addition to the examination at these points, samples were collected to show the relation between local situations and municipal water supplies and to ascertain the character and extent of the pollution which might be due to vessels navigating boundary waters. Both surface and deep samples were simultaneously taken at certain

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points in the St. Clair, Detroit, and Niagara Rivers in order to determine the effect of stratification. While some situations show definite stratification, it may be accepted in interpreting the results that for the waters under investigation surface samples measure directly the extent of bacterial pollution.

The investigations were essentially bacteriological and the work was continued at each sample-collection point during a period of time sufficient to observe the quality of water, irrespective of minor variations.

Other data collected.

Besides this bacterial examination, some float and temperature observations were made and inquiries were carried on and data collected and compiled as to area, population, location of water-supply intakes, quantity of sewage discharged, for each of the several municipalities in the areas under investigation.

Meteorological data relative to the several points of investigation for the periods of examination were furnished by the meteorological departments of the United States and Canada, and the State and provincial health bodies assiduously supplied the commission with such vital statistics as were available. From these statistics the death rate from typhoid fever per 100,000 has been computed for each of the municipalities either abstracting water from or draining into the boundary waters.

The immense amount of information thus gathered and presented to the commission appears in the report of the sanitary experts. Maps were prepared to show the location of sample collection points, and charts and tables to show the bacterial counts, *B. coli* averages per 100 cubic centimeters for each of the sample collection points, together with the dates of collection and the maximum amounts encountered during the period of examination. This material was published with the progress report of the commission under date of January 16, 1914.[1]

Investigations at sittings of commission.

With the object of obtaining information in addition to what had been gathered by the sanitary experts in their exhaustive investigation, the commission held sittings at many places along the border and took the evidence of a large number of people who were acquainted with the insanitary conditions of several of the districts affected by pollution. Members of the commission also personally examined most of the points where pollution was strongly complained of.

Messrs. Streeter and Powell, as a committee of the commission, took evidence at Buffalo in the month of June, 1913, touching the

[1] Progress report of the International Joint Commission on the reference by the United States and Canada in re the Pollution of Boundary Waters. Including report of the sanitary experts. 1914.

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extent of pollution in the Niagara River and the effect of this pollution upon the riparian towns on the United States side of the river.[1] Subsequently, during the months of September, October, and November, 1914, and the months of June and August, 1916, meetings of the commission, at which the pollution of boundary waters was inquired into, were held at a number of places along the Niagara, Detroit, and St. Clair Rivers.[2, 3]

Conference with sanitary engineers at New York.

In order that the commission should, in a matter of such vital importance as was being investigated, know the attitude of leading exponents of sanitary science, it prepared and submitted a series of questions to a number of sanitary engineers of large experience and wide reputation in the United States and Canada, namely: Mr. George W. Fuller, of New York City; Prof. Earle B. Phelps, of the United States Public Health Service; Mr. George C. Whipple, of Harvard University; Mr. W. S. Lea, of Montreal; Mr. T. J. Lafrenière, of the Provisional Board of Health of Quebec; and Mr. F. A. Dallyn, of the Provincial Board of Health of Ontario. These six engineers afterwards, on the invitation of the commission, attended a conference with it in the city of New York.[4] They are hereafter referred to as the "advisory engineers." Some days were spent in their examination, but the lengthy testimony they gave was condensed by them into a résumé of 14 points, as follows:[5]

Résumé of testimony.

1. Speaking generally, water supplies taken from streams and lakes which receive the drainage of agricultural and grazing lands, rural communities, and unsewered towns are unsafe for use without purification, but are safe for use if purified.

2. Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are safe for use after purification, provided that the load upon the purifying mechanism is not too great and that a sufficient factor of safety is maintained, and, further, provided that the plant is properly operated.

3. As, in general, the boundary waters in their natural state are relatively clear and contain but little organic matter, the best index of pollution now available for the purpose of ascertaining whether a water-purification plant is overloaded is the number of *B. coli* per 100 cubic centimeters of water expressed as an annual average and determined from a considerable number of confirmatory tests regularly made throughout the year.

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[1] Preliminary report of committee having general supervision of the investigation relating to the pollution of boundary waters; with documents * * * relating to the petitions of the Erie and Ontario Sanitary Canal Co. for permission to divert 6,000 second-feet from Lake Erie. 1913.

[2] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada. 1914.

[3] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada. 1916.

[4] Conference with sanitary engineers at New York City, May 26 and 27, 1914.

[5] Résumé of testimony of consulting sanitary engineers in the matter of the pollution of boundary waters, New York, 1914.

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4. While present information does not permit a definite limit of safe loading of a water-purification plant to be established, it is our judgment that this limit is exceeded if the annual average number of *B. coli* in the water delivered to the plant is higher than about 500 per 100 cubic centimeters, or if in 0.1 cubic centimeter samples of the water *B. coli* is found 50 per cent of the time. With such a limit the number of *B. coli* would be less than the figure given during a part of the year and would be exceeded during some periods.

5. In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby.

6. While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters.

7. The nature of the sewage treatment required should vary according to the local conditions, each community being permitted to take advantage of its situation with respect to local conditions and its remoteness from other communities, with the intent that the cost of sewage treatment may be kept reasonably low.

8. In general, the simplest allowable method of sewage treatment, such as would be suitable for small communities remote from other communities, should be the removal of the larger suspended solids by screening through a one-fourth inch mesh or by sedimentation.

9. In general, no more elaborate method of sewage treatment should be required than the removal of the suspended solids by fine screening or by sedimentation, or both, followed by chemical disinfection or sterilization of the clarified sewage. Except in the case of some of the smaller streams on the boundary, it is our judgment that such oxidizing processes as intermittent sand filtration and treatment by sprinkling filters, contact beds, and the like, are unnecessary, inasmuch as ample dilution in the lakes and large streams will provide sufficient oxygen for the ultimate destruction of the organic matter.

10. Disinfection or sterilization of the sewage of a community should be required wherever there is danger of the boundary waters being so polluted that the load on any water-purification plant becomes greater than the limit above mentioned.

11. It is our opinion that, in general, protection of public water supplies is more economically secured by water purification at the intake than by sewage purification at the sewer outlet, but that under some conditions both water purification and sewage treatment may be necessary.

12. The bateriological tests which have been made in large numbers under the direction of the International Joint Commission indicate that in most places the pollution of the boundary waters is such as to be a general menace to the public health should the water be used without purification as sources of public water supply or should they be used for drinking purposes by persons traveling in boats.

13. It is our judgment that the drinking water used on vessels traversing boundary waters should not be taken indiscriminately from the water traversed, unless subjected to adequate purification, but should be obtained preferably from safe sources of supply at the terminals.

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14. While recognizing that the direct discharge of fecal matter from boats into the boundary waters may often be without danger, yet in the interest of effective sanitary administration it is our judgment that the indiscriminate discharge of unsterilized fecal matter from vessels into the boundary waters should not be permitted.

These views of the advisory engineers were given after most mature consideration on their part, and not only have they been of great assistance to the commission in arriving at the conclusions and recommendations expressed in this report, but their thoroughness and exhaustiveness have been recognized by scientists on this continent and in Europe, frequent applications having been made to the commission for copies of both the testimony and the résumé.

Engineering investigations.

It was necessary that the commission should form some reliable estimate of the cost of installing the requisite remedial works, and it determined to carry on its investigations in such detail that the engineering possibilities and difficulties would be fully considered and the cost of the ultimate projects determined within reasonably close limits. Prof. Earle B. Phelps, of the United States Public Health Service, was engaged as the commission's consulting engineer and was put in charge of the investigation. Engineering offices were established at Detroit and Buffalo, each office comprising a small but well-organized force, under Prof. Phelps' supervision, but in immediate charge of a district engineer. The Detroit office had charge of the investigation in the cities and towns bordering upon the St. Clair and Detroit Rivers, and the Buffalo office had charge of the investigation along the Niagara River. The investigations covered the following cities and towns:

In the United States: Port Huron, St. Clair, Marine City, Algonac, Detroit, River Rouge, Ecorse, Ford City, Wyandotte, Trenton, Lackawanna, Buffalo, Tonawanda, North Tonawanda, Lasalle, Kenmore, Niagara Falls, Lewiston, and Youngstown.

In Canada: Sarnia, Ford, Walkerville, Windsor, Sandwich, Amherstburg, Fort Erie, Bridgeburg, Chippewa, Niagara Falls, Queenston, and Niagara-on-the-Lake.

All of these cities and towns were asked to assist in the investigations in which they were respectively concerned. The examinations at Detroit and Buffalo were of much greater magnitude than the others, and this fact, coupled with the wish of the commission that these cities should be associated with the investigation in which they were interested, led to an invitation being extended to their officials to collaborate with the consulting sanitary engineer in the prosecution of his work; and the commission expresses its appreciation of their sympathetic and efficient cooperation.

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Cooperation of public authorities.

On December 5, 1914, Detroit appointed Mr. Clarence W. Hubbell, a consulting sanitary engineer, to review the data and the conclusions of the commission's sanitary experts, and to report what means, if any, should be adopted by the city for the purification of its sewage, and to what extent it would be justified in incurring expense for that purpose. Mr. Hubbell's office cooperated most closely with the commission's Detroit office during the whole period of the investigation so far as the work related to Detroit; and the commission is pleased to report that his recommendations to the city and the recommendations of the consulting engineer of the commission are in substantial accord. Buffalo furnished office space and equipment for the commission's staff at that city and furthered the progress of the investigation by supplying all information in its possession and by rendering valuable assistance to the commission's engineers, in addition to making readily available all city maps and documents required.

The commission also expresses its satisfaction with the readiness and promptness with which the smaller cities and towns furnished the maps, data, and information in their possession. The Provincial and State health authorities also afforded the commission's engineers valuable assistance by providing them with maps and data in their possession relating to the sewerage systems of those cities and towns. This was particularly the case in the Province of Ontario. The reports of the Chief of Engineers of the United States Army supplied hydraulic data of great importance, especially the data dealing with Great Lakes levels, river discharges, and elevations.

Treatment projects.

The investigations began in March, 1915, and were completed in March, 1916. In carrying them out it was necessary to prepare plans for treatment works adapted to local requirements and sufficient for the general needs of the situation. For economic reasons the consulting engineer adopted the existing sewerage systems as points of departure. When available, sites for treatment works were tentatively determined upon and the necessary collecting systems were planned to bring the sewage to these points. This procedure was necessarily largely experimental, as there were usually several possible and available sites for treatment works and frequently more than one possible system of main drainage. It was also necessary to plan these works with due regard to the future growth of the cities, and consequently in some instances sewer interceptors were planned for sections thereof almost wholly undeveloped. This procedure generally led to the tentative adoption of several major projects, all of them feasible and practicable, but differing in the type of treatment works, in the number and location of the concentration points for treatment, the arrangement of trunk-

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line interceptors, and the substitution in some cases of pumping-station plants for deeper interceptor construction. In each case these various projects were worked out in detail, the necessary structures were designed to a point sufficient for comparative cost estimates, and they were then compared upon the basis of cost and general desirability. No attempt was made to exhaust all the possibilities; and it is not assumed that the remedial works planned are the most economic or desirable. Neither time nor funds were available for field surveys, except in some minor instances, such surveys not being considered essential to the work. The engineering investigations were naturally and necessarily much less detailed than would be those in connection with a city about to construct new works. They were, however, in sufficient detail to develop in the case of all cities and towns feasible and workable plans for the collection and treatment of their sewage. The estimated cost is ample for the application of satisfactory remedial measures. Details of the proposed plans for collecting and treating the sewage of the various cities and towns are set forth in the report of the consulting engineer.[1]

Meetings.

As soon as this report was submitted to the commission it was printed, and copies were supplied to the different municipalities along the Niagara, Detroit, and St. Clair Rivers, with an invitation to attend the meetings of the commission held, as before mentioned, at Buffalo and Detroit in June, 1916.[2] At these meetings the remedies suggested by the consulting engineer were discussed with the representatives of the various municipalities interested. A meeting of the commission was also held at Ogdensburg in August, 1916, at which a large number of the municipalities on the upper St. Lawrence were represented by their mayors, city engineers, and health officers.

The commission also devoted considerable attention to the investigation of existing methods of sewage disposal.

[1] Report of the consulting sanitary engineer upon remedial measures, Mar. 8, 1916.
[2] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada. 1916.

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III.—EXISTING POLLUTION.

The first question in the reference is—

To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to the public health and unfit for domestic or other uses?

To enable the commission to answer this question the detailed bacteriological examination hereinbefore described was made by the sanitary experts. A brief epitome only of their report can be given here. An extensive examination was made of the waters in Thunder Bay and White Fish Bay of Lake Superior, the lower end of Lake Huron, and the eastern ends of Lake Erie and Lake Ontario. They were found to be practically free from *B. coli* in 100 c. c. quantities, and to have a bacterial count of less than 10 on agar at 37° C. This, then, is the condition of the water as it enters the St. Marys, St. Clair, Niagara, and St. Lawrence Rivers. The lower portions of Lake St. Clair and Rainy Lake, the sources of the Detroit and Rainy Rivers, respectively, while appreciably polluted by agricultural and other drainage, show a remarkable freedom from extensive bacterial pollution.

Sources and extent of pollution.

The waters of Rainy River, St. Marys River, St. Clair River, and of the Detroit and Niagara Rivers, in consequence of the unrestricted discharge of sewage from vessels and towns, are no longer fit for domestic use unless subjected to extensive treatment in water-purification plants. Below the cities of Detroit and Buffalo the waters of the Detroit and Niagara Rivers, respectively, are so intensely polluted that it is highly questionable whether by the aid of any ordinary purification plant they can be made at all suitable for drinking purposes.

The waters of Rainy Lake, Rainy River, and Lake of the Woods were examined during the period from July 8 to July 22, 1913. In this examination 995 specimens were collected and reported upon. The waters of Rainy Lake, subjected to agricultural drainage, showed a pollution amounting to 19 *B. coli* per 100 c. c., presumably the effect of this drainage, and of the construction of a big fill for railway purposes. The drinking water of the towns of Fort Frances and International Falls is taken from the head of Rainy River, and

Rainy Lake, Rainy River, Lake of the Woods.

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was found to be seriously contaminated owing to the discharge of polluting matter in the vicinity of the respective waterworks intakes. Below the falls a very considerable pollution, averaging about 300 *B. coli* per 100 c. c., exists throughout the length of the river. This is mainly attributable to the discharge of raw sewage by these towns. The polluted condition of the river is augmented by drainage from farms and small villages located at intervals along its banks, and markedly by sewage from the towns of Rainy River and Baudette.

An examination was made of the water in the Lake of the Woods in the vicinity of the mouth of Rainy River and showed an average of only 34 *B. coli* per 100 c. c. It appears that the self-purification and dilution had here operated to lessen pollution in the river.

Rainy River throughout its entire course has been rendered unfit for domestic uses owing to the unrestricted discharge of sewage and other wastes. The population along the banks is sparse, with the exception of that of the villages and towns. If subjected to extensive water purification, the river may be used as a source of drinking-water supply.

Thunder Bay.

The waters of Thunder Bay were examined during the period from July 28 to August 15, 1913. In all, 922 samples of water were collected and reported upon. Thunder Bay is extensively polluted in the neighborhood of the towns of Port Arthur and Fort William, but not to such an extent as to affect Lake Superior.

St. Marys River.

The waters of the St. Marys River were examined during the period from June 28 to July 16, 1913, 1,065 samples being collected and reported upon. The results of the investigation show that Lake Superior at the head of the St. Marys River is practically pure. In White Fish Bay the pollution measures 6.5 *B. coli* per 100 c. c. The discharge of sewage from vessels was shown to seriously pollute the waters in the lanes of vessel travel. Especially does vessel pollution menace the water supplies of the towns of Sault Ste. Marie (Mich.) and Sault Ste. Marie (Ontario). The average pollution at the waterworks intake of the former city during investigation was about 25 *B. coli* per 100 c. c., and at the waterworks intake of the latter over 200 *B. coli* per 100 c. c. Below the towns the pollution was shown to increase to 291 *B. coli* per 100 c. c. A serious condition of the river continues, although in a less pronounced degree, down to Neebish Island.

The pollution present in this river, due to the discharge of raw sewage by vessels and by the two towns of Sault Ste. Marie, affects very seriously the only available water supplies for summer residents and for pleasure boats frequenting its waters. Water examined in the Straits of Mackinac proved to be quite pure.

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Lake Huron, St. Clair River, Lake St. Clair.

The laboratories stationed at Port Huron, Detroit, and Sarnia were in operation during May, June, July, and August, 1913, for the examination of the waters of the lower end of Lake Huron, River St. Clair, and Lake St. Clair. In all, 2,336 samples were examined and reported upon. The examination showed that the waters of Lake Huron at the head of the river would be practically free from *B. coli* were it not for the pollution from vessel sewage. Samples taken about 10 miles up the lake showed absence of *B. coli* even in 100 c. c., while the water at the lower end, where vessel pollution is concentrated, showed an average of 9 *B. coli* per 100 c. c. Below the towns of Port Huron and Sarnia the waters of the St. Clair River for a stretch of about 34 miles are quite unfit for drinking purposes unless extensively treated, the *B. Coli* content found in the river water exceeding 200 per 100 c. c. The pollution below these towns is due to the combined effects of the discharge of untreated sewage from vessels and the towns along the shores. Any tendency toward self-purification of the river by natural agencies is counterbalanced by the sewage and drainage from the small villages and residences along its course.

Lake St. Clair, which receives the discharge of the river, showed less evidence of pollution. Natural agencies promote in the lake a purification not found in the river.

Detroit River and western end of Lake Erie.

The laboratories for the study of the Detroit River and the western end of Lake Erie stationed at Detroit, Windsor, Amherstburg, and on the United States revenue cutter *Morrill*, were operated during the months of May, June, July, August, September, and October, 1913. Some 5,353 samples were collected and examined, including those taken in the western end of Lake Erie and at the mouth of the Detroit River. The situation with reference to the Detroit River is described by the sanitary experts in their report to the commission in 1914,[1] as follows:

> The results of our analyses of samples taken above the intake for the Detroit city water supply showed this to be an unsafe source of supply without careful treatment. * * * Samples taken along the several cross sections from this point to the site of the Michigan Central tunnel showed a marked increase of pollution in the shore samples.
>
> The water intakes of Walkerville and Windsor are both located in dangerous situations, owing to the discharge of sewage above these intakes and to a potential danger of climatological variation diverting the intense shore pollution to points from whence it would affect the water intakes. In spite of the efforts made by these towns to protect their supplies by means of chlorination,

[1] Progress report of the International Joint Commission on the Reference by the United States and Canada in re the Pollution of Boundary Waters. Including report of the sanitary experts. 1914.

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the typhoid rates remain too high. At times the pollution is so great that the quantity of chlorine required to overcome it gives an objectionable taste to the water.

* * * * * * *

Samples taken from a cross section over the Michigan Central Railroad tunnel showed gross pollution at sample points near the Canadian and United States shores, and a considerable pollution extending across the entire river. Samples taken from several cross sections showed gross pollution throughout the entire river from the Michigan Central Railroad tunnel to Fighting Island.

From Fighting Island to the mouth of the river the water is grossly polluted and totally unfit as a source of water supply. It is our opinion that such raw water would impose an unreasonable responsibility on any known method of purification, even with the most careful supervision. Unfortunately, Wyandotte, Trenton, and Amherstburg are taking their water supplies from this part of the river.

The extensive pollution of the Detroit River is perhaps better indicated by saying that at its head the *B. coli* count is approximately 5 per 100 c. c., and in the lower portions just below Amherstburg it reaches the enormous figure of 10,592 *B. coli* per 100 c. c.

The pollution in the Detroit River is occasioned by the discharge of raw sewage from its riparian communities, notably the city of Detroit, and by the sewage from vessels.

The investigations at the laboratories at Detroit, Windsor, and Amherstburg show that while the waters of the western end of Lake Erie are extensively polluted by the flow of the Detroit River, this pollution does not extend past the islands which separate this end from the remainder of the lake.

Lake Erie.

Lake Erie, outside of this polluted area and the polluted areas at the mouths of its tributaries and its littoral waters, affords a remarkable instance of self-purification. The purity of the main body of the lake was amply established by examination of its water at several widely separated stations.

Niagara River.

The laboratories for the study of the Niagara River established at Buffalo, Port Erie, Niagara-on-the-Lake, and Youngstown were operated during the months of May, June, and July, 1913, 4,137 samples of water being collected and examined. This investigation showed that above Niagara Falls the great bulk of the pollution in the river, and due to the discharge of sewage therein, is confined to the marginal waters of the country in which it originates and that the sewage of Buffalo is polluting to a serious extent the available water supplies of the two Tonawandas and the city of Niagara Falls, N. Y.

The effect of the pollution of the lower Niagara is to render the river water totally unfit for domestic uses unless purified. All of the lower municipalities have been forced to install and operate water-purification plants, and the results of their operation show

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only too clearly that the use of the water is accompanied by no proper margin of safety.

Lake Ontario.

The investigation revealed the fact that the waters of Lake Ontario are comparatively free from *B. coli*, with the exception of an 18-mile radius from the mouth of the Niagara River, of limited areas at the mouths of other rivers, and of the littoral waters of the lake and of the lanes of vessel travel.

St. Lawrence River.

The laboratories operated at Kingston and Clayton, as well as at Montreal, during the months of April, May, and August, 1913, for the purpose of examining the waters of the St. Lawrence River, collected and examined 1,890 samples.

The St. Lawrence River is the only water supply available for the summer residents at the Thousand Islands and for the communities along its banks.

During the period of examination it was observed that the present practice of unrestricted discharge of sewage renders certain areas unfit sources of drinking water. Before the tourists appear in June, with the consequent increase of boat traffic, the waters are in a remarkable state of purity. Below the Thousand Islands population is denser and considerable pollution exists throughout the river, the source of which is the discharge of sewage from vessels and from the riparian communities.

St. John River.

The laboratories stationed at Van Buren in October, 1913, for the study of the St. John River collected and examined 672 samples. The pollution in this river amounted to about 125 *B. coli* per 100 c. c. in the late fall. This is excessive in comparison with the figures in the Detroit and Niagara Rivers, population and stream flow considered. This abnormal condition is attributable in large measure to the potato starch factories located along this river, the waste from which contains large numbers of bacteria capable of fermenting lactose.

Vessel pollution.

Reference has already been made to the numerous vessels navigating boundary waters and their enormous floating population and the pollution resulting therefrom. This pollution not only clearly exists in boundary rivers, in harbors, and in the vicinity of water intakes, but was found to a harmful extent in the Great Lakes, where its presence is due to the fact that vessels navigating lake waters ply in comparatively narrow lanes in order to avoid collision in the nighttime or during fog. Upbound vessels follow one track and down-bound vessels follow another, and the pollution is confined to the vicinity of these lanes.

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Pollution from vessels is of two kinds: (1) Raw sewage in the shape of human excreta, garbage, etc., and (2) water ballast discharged by vessels on approaching ports of designation. This pollution is a serious menace to public health, not alone through the possible contamination of the public water supplies near their intakes, but also by reason of its effect upon the water supplies of other vessels following or crossing the same routes.

Sawmill and industrial wastes.

Complaints were made to the commission regarding a form of pollution which is not of a bacteriological character, existing in the St. John and Rainy Rivers. It results from the deposit of sawdust and other sawmill wastes in the streams, frequently causing nuisances by making the shores and bed of the stream unsightly, unclean, and malodorous. This pollution is also injurious to fish life. At International Falls and at Fort Frances objection was also made to the discharge of wastes from the pulp mills on the Rainy River. Like complaints were made with respect to the St. Croix River, which in part forms the boundary line between New Brunswick and the State of Maine. The pollution complained of in the case of the pulp mills was chiefly due to chemical waste resulting from the manufacture of pulp. This form of pollution is also injurious to fish life and the fishing industry. The pollution from sawmill and pulp-mill wastes has in every instance transboundary effects detrimental to property and health.

With the exception of sawmill and pulp-mill wastes no reference has been made to industrial and chemical wastes as a source of pollution. Contamination from these sources is at present so limited and local in its extent that the commission did not regard it as of sufficient moment from an international standpoint to call for any extensive scientific investigation. Unquestionably in the future, unless preventive measures are taken, pollution from all these wastes will have a very injurious effect, and the commission has not been unmindful of this fact in preparing the recommendations hereinafter made.

Typhoid fever statistics.

The grossly polluted condition of boundary waters is doubtless the cause of the abnormal prevalence of typhoid fever throughout the territory bordering thereon.

The table following gives the statistics of death from typhoid fever in the cities and towns therein mentioned for a period of 14 years, beginning with the year 1903:

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Typhoid death rates per 100,000 of population.

	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916
Rainy River:														
International Falls, Minn														
Fort Frances, Ontario	665	665	775	96	86	133	66	393	342	0	72	0	0	0
Baudette, Minn.														
Rainy River, Ontario	0	0	200	200	0	0	0	0	63	0	0	0	0	63
St. Mary's River:														
Sault Ste. Marie, Mich	115	52	68	59	17	73	56	24	54	23	22	29	7	7
Sault Ste. Marie, Ontario	152	26	150	191	91	68	90	154	280	85	127	84	24	31
St. Clair River:														
Port Huron, Mich	25	35	15	56	46	21	58	74	48	197	10	0	5	30
Sarnia, Ontario	116	34	33	55	87	110	82	101	148	139	45	26	34	60
etroit River:					*									
Detroit, Mich	20	17	20	21	25	19	20	23	16	17	29	13	13	15
Walkerville, Ontario	0	47	0	40	0	35	0	0	30	57	25	0	0	0
Windsor, Ontario	30	59	42	41	78	63	56	49	34	38	10	27	35	0
Sandwich, Ontario	122	182	57	54	52	96	47	47	0	173	35	34	35	0
Wyandotte, Mich	(1)	(1)	(1)	72	107	123	87	75	12	54	92	33	47	63
Trenton, Mich		166	0	164	163	80	80	0	163	0	243	0	80	0
Amherstberg, Ontario	0	0	0	83	0	0	40	0	78	118	37	0	42	85
Niagara River:														
Buffalo, N. Y.	34	24	24	23	28	20	24	20	25	12				
Fort Erie, Ontario	0	108	0	0	99	0	0	0	87	0	0	0	0	0
Bridgeburg, Ontario	0	0	0	0	0	68	0	0	0	0	56	0	0	0
North Tonawanda, N.Y.				28	46	53	51	42	97	16	15	60	29	36
Niagara Falls, N. Y.	127	140	181	150	131	103	87	98	194	67	23	10	0	10
Niagara Falls, Ontario	0	14	0	40	38	84	26	60	90	44	85	34	9	27
Lewiston, N. Y.											0	0	0	0
Youngstown, N. Y.											0	0	0	0
Niagara-on-the-Lake, Ontario	0	78	78	0	0	0	0	0	0	0	0	0	0	60
St. Lawrence River:														
Cape Vincent, N. Y.											0	0	0	0
Kingston, Ontario	100	22	38	38	27	32	32	80	26	32	25	43	28	5
Clayton, N. Y.											0	0	0	53
Gananoque, Ontario	55	0	0	0	27	0	0	0	0	0	0	0	0	0
Alexandria, N. Y.											0	48	48	0
Brockville, Ontario	66	66	22	109	21	43	32	10	42	64	10	72	162	0
Ogdensburg, N. Y.	54	61	40	86	39	32	25	50	31	37				
Prescott, Ontario	0	0	34	34	103	34	0	70	36	0	0	0	0	36
Cornwall, Ontario	30	45	30	90	75	111	64	64	48	61	15	30	77	73

[1] Average for years 1889–1905, 85 deaths.

It may be incidently mentioned that there is a marked improvement in the statistical showing in the period since the commission's investigation in 1913. This is largely attributable to the fact that in consequence of this investigation greater efforts have been made to protect water supplies by the use of bleaching powder and liquid chlorine. The condition, however, is still far from satisfactory. Notwithstanding the general improvement, violent outbreaks of typhoid fever have occurred, and the potential danger must continue to exist in view of the extensive pollution of these waters and the limitations and inefficient operation of water-purification plants. Not only have the border communities suffered from this condition, but the navigation interests have also been injured very severely from the disastrous outbreaks consequent on the use of polluted boundary water.

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IV.—TRANSBOUNDARY EFFECTS OF POLLUTION.

This report so far has dealt with pollution generally in boundary waters. The reference as amended calls for a further inquiry into pollution of the waters on one side of the boundary line which may extend to and effect those upon the other side. Some persons who appeared before the commission argued for a literal interpretation of the language of the amended reference and suggested that the only pollution with which the commission is concerned is that which actually crosses the boundary line and has a transboundary effect. While the commission does not accept this narrow interpretation, it must consider the extent to which, and the places at which, pollution has such an effect.

Detroit River.

The most intense and the most clearly demonstrable cases of pollution crossing the boundary exist in the Detroit and Niagara Rivers. The city of Detroit discharges into the former all the raw sewage from its estimated population of 850,000. On the United States side opposite Amherstburg the pollution of the river reaches the enormous figure of 10,392 *B. coli* per 100 c. c., and its waters from that point to Lake Erie and the waters of that lake within a radius of about 4 miles from the mouth of the river are very greatly polluted. Beyond question the pollution from Detroit and the towns lower down the river crosses the boundary line and affects detrimentally health and property on the other side. A notable example of this is to be found in the condition of the shore waters of Bois Blanc Island, a summer resort on the Canadian side of the river which is extremely popular, especially with the inhabitants of Detroit. The island shore waters are very greatly polluted by the sewage from that city. The transboundary effect of this pollution may be estimated from the data given in Tables XII, XIII, and XIV, and the maps opposite pages 38, 39, 40, 41, and 42 of the Progress Report. Transboundary effects are detectable along the lower stretches of the river generally. Owing to the comparative smallness of the towns on the Canadian side, it is not at present possible to trace pollution from them across the boundary, but these towns are growing rapidly, and if they ever attain anything like the size of Detroit or Buffalo, unless successful preventive or remedial measures are adopted, the river will be absolutely unfit for domestic purposes.

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Niagara River.

In the Niagara River, owing to the discharge into it by the city of Buffalo of the sewage of an estimated population of 500,000, the waters below the city on the United States side are grossly polluted. This pollution is increased by the sewage from towns on both its banks but particularly from towns on the United States side. Until the Falls are reached the great bulk of the pollution, as has already been stated, is confined to the marginal waters into which it is discharged. At the Falls and in the rapids below the Falls, however, the waters are thoroughly intermixed; and the entire river from the whirlpool to Lake Ontario shows an intense pollution from shore to shore and from the surface to the bed of the stream. The flow of such an enormous quantity of grossly polluted water into the lake contaminates its waters for a radius of about 18 miles from the river's mouth. The intensity of this pollution may be judged from the data given in Table XIX on page 48 and on the map facing that page of the progress report. This map shows that the maximum average of *B. coli* per 100 c. c. at several points in this polluted area of the lake during the period of examination by the sanitary experts was 10,000. The Canadian area of this portion was found to be much more densely polluted than the United States area, the map showing at some points in the former, distant about 10 miles from the mouth of the river and about 6 miles from the international boundary line, a maximum average count of 1,000 *B. coli* per 100 c. c.

Rainy, St. Marys and St. John Rivers.

There is a well-marked crossing of pollution from one side to the other in the case of the Rainy River, the St. Marys River, and the St. John River, although much less pronounced than in the cases of the Detroit and Niagara.

Other boundary rivers.

In the remaining boundary rivers pollution does not exist to as great an extent as in the Niagara and Detroit; and its transboundary effect, where such effect exists, is not easy of detection. The communities along their banks which have sewerage systems all discharge raw sewage into the streams. It was contended that the polluting material discharged into them "hugs their shores," and while the effect may be very harmful to the health and property of lower communities on the same side of a river, its effect upon the waters on the other side of the boundary may be, and in the case of the larger rivers is, practically nil. In judging of the transboundary results of pollution people are ordinarily influenced by the lack of palpable effect at or near the point where the sewage is discharged. In all of the boundary waters, notwithstanding the disposition on the part of the urban sewage they receive "to hug the shore" (assuming

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there is such a disposition), winds, cross currents, eddies, rapids, shoals, reefs, ice jams, differences in specific gravity between the sewage and the water of the streams, the form and varying courses of the channel, and the churning of the waters by the propellers of steamboats may, and in some cases do, cause such a commingling and diffusion of their waters that the pollution originating on one side is carried to some extent to the other side of the stream, although the contaminating element may be so colorless as not to be detectable by the eye. Even in cases where transboundary evil results can not be proved the probability of the pollution on one side passing over or affecting the waters on the other side of the boundary line is so great that the inhabitants on the latter side should not be forced to run the consequent risk to life, health, and property. The idea is deeply rooted in the minds of many that running water always purifies itself. This belief was put forward by some as a reason why no action should be taken in respect to these rivers. Undoubtedly water does purify itself if it receives no accretions of contamination and runs in its course a sufficient length of time. The banks of these remaining boundary rivers are generally densely peopled, and the communities along their course discharge their sewage untreated into them, thus more than counteracting this cleansing or purifying influence.

The Great Lakes.

The waters of the Great Lakes constitute a class by themselves, and except at the points where the Niagara and Detroit Rivers enter Lake Erie and Lake Ontario, respectively, there is no pollution in them which crosses from one side of the boundary line to the other, except it may be vessel pollution. This is clear when the condition of the central portions of the lakes is considered. Outside of a margin along their shores and the polluted areas at the mouths of the rivers tributary to them, these waters are, with the exception of places where pollution from vessels exists, in their pristine purity. Take Lake Ontario and Lake Erie for examples. Notwithstanding the facts that these lakes are fed entirely by streams more or less polluted, including the Niagara and Detroit Rivers, with their immense flow of extremely contaminated water, and that there is poured into them the raw sewage of several very large cities and towns, so efficacious is the self-purifying power of water that, with the exception of this littoral margin and of those limited areas at the mouths of the tributary rivers, their waters, when unaffected by vessel pollution, are absolutely pure. This condition is an interesting one. The purifying power of nature, assisted by time, accomplishes here what human agencies and human resources find it impossible to duplicate.

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Transboundary effects of vessel sewage.

Vessel sewage, which was found on examination by the sanitary experts to be a much greater factor in polluting boundary waters than is generally supposed, is a matter of great international moment, and must be referred to in this connection. The commission does not commit itself to any view of the fiction or theory of vessel territoriality, which has been much discussed by writers of international law, but a vessel may, and for the purpose of this investigation the commission thinks should, be looked upon as a portion of the territory of the State from which she hails or in which she is registered. If sewage is discharged by a vessel on her own side of the boundary and then passes over the line, and there affects harmfully health and property, the treaty is violated both in letter and in spirit. Is violation of the treaty, however, limited to cases of this kind? The words of the treaty are broader than the language of the reference. The latter, taken literally, deals with pollution in boundary waters on one side of the boundary, which extends to and affects the waters on the other, or which, in other words, has both a transboundary extension and a transboundary effect. To bring pollution within the treaty it need only have one of these features—a transboundary effect.

It might not be straining too much the language of the treaty, "health and property on the other" (meaning the other side of the boundary line), to regard it as indicative of national ownership or sovereignty rather than location. This construction, for instance, would prohibit the pollution of Canadian boundary waters that might injure citizens of the United States who for the time being were exercising their treaty right to free and open navigation of these waters, and would also prohibit pollution of the United States boundary waters by Canadian vessels discharging their sewage therein. If the language is susceptible of this interpretation, such a construction would certainly be consonant with the spirit of the treaty.

Independently of the point whether this construction is or is not warranted, the relations of the United States and Canada, especially with regard to boundary waters, demand that the question of their pollution should be treated on the broadest possible lines.

International situation along boundary waters.

The international situation along the boundary line is a phenomenal one. Not only is it one of the most vital practical importance to each country, but it is one on which each nation may felicitate itself as affording a great object lesson to the world, showing how two liberty-loving, morally directed, and law-abiding peoples can live side by side in the spirit at once of friendly rivalry and perfect peace. Along the thousand miles of their territorial contact from the At-

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lantic to the Pacific there is nothing which suggests the existence of enmity or the possibility of military strife. The provision of the treaty of Ghent that "there shall be a firm and universal peace between His Britannic Majesty and the United States, and between their respective countries, territories, cities, towns, and people of every degree, without exception of places or persons," has happily fair promise of perpetual observance. Practically the two peoples commingle with all the freedom consistent with the physical and political barriers which separate them. This condition has led to an interweaving of interests which makes the bond between them one of more than international comity. The treaty right of navigation is exercised at present to an enormous extent, and in the future will be exercised to a still greater extent. Along the boundary waters the citizens of both countries fraternize socially, select and patronize their summer resorts, invest their capital and engage in industries and enterprises, almost without regard to territorial sovereignty. Such freedom of intercourse, however laudable, has the attendant danger of being conducive to the spread of disease and infection if either country fails to observe sanitary principles. The pollution of drinking water supplies and of bathing waters at Bois Blanc Island, on the lower Niagara, at the Thousand Islands, or at other summer resorts, or of the waters navigated by vessels and yachts, might not only be an injury to the immense number of citizens of both countries who would be brought immediately in contact with the pollution, but would indirectly be a source of great peril to hundreds of thousands more. To illustrate the danger the following citation is made from the United States Public Health Service Report for 1914, volume 29, page 393:

> It is stated that during one short period of the summer's cruise (referring to the voyage of a lake boat) 77 cases of typhoid fever developed as the result of the use of impure drinking water taken from the Detroit River. * * *.
> * * * Investigations by this service of similar outbreaks on three Great Lakes vessels during the summer of 1913 showed that out of a total of 750 people there were over 300 cases of diarrhea and 52 cases of typhoid with 7 deaths.

The lamentable prevalence of typhoid fever referred to previously calls for consideration in this broad international view of the question of pollution of boundary waters.

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V.—INJURY TO HEALTH AND PROPERTY WITHIN THE MEANING OF THE REFERENCE.

Language of reference and treaty.

The commission having ascertained the necessary facts, both as to the extent and effects, including the transboundary effects, of existing pollution, was confronted with the very difficult problem of deciding whether or not the effect of this pollution was an "injury" to health and property within the meaning of the reference. From the language of the second question in the reference it is evident that the object which the two Governments had in view in making the submission was, as has been previously stated, to see that the treaty was observed in its integrity. This object is expressed as follows:

> In order * * * to fulfill the obligations undertaken in Article IV of the treaty.

Article IV, so far as it is necessary to quote it, reads as follows:

> It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other.

The controlling words of this prohibition are "to the injury of health or property on the other." It is necessary to consider the meaning which is to be attached to the word "injury." Does it mean simply harm or damage, actual or potential, to health or property, without regard to any extrinsic considerations, such as justification or excuse on the part of those who cause the damage or ease of avoidance on the part of those who suffer from this harm or damage? It appears to the commission that a broader and more liberal view should be taken than would suggest an affirmative answer to this question. It is necessary to consider the language of the reference and of the treaty, and also the law and practice of both countries with respect to the pollution of waters.

Pollution of water courses at common law.

The common law respecting rights in streams is admirably set forth in the leading textbooks of both countries on "waters," and is especially well summarized by Lord Macnaghten in the case of *Young* v. *Sankier Distillery Co. et al.*, decided by the British House of Lords in 1893.[1]

> A riparian proprietor is entitled to have the water of the stream, on the banks of which his property lies, flow down as it has been accustomed to flow down to his property, subject to the ordinary use of the flowing water by upper pro-

[1] Appeal cases, House of Lords and Judicial Committee of the Privy Council, 1893, p. 698.

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prietors, and to such further use, if any, on their part in connection with their property as may be reasonable under the circumstances. Every riparian proprietor is thus entitled to the water of his stream, in its natural flow, without sensible diminution or increase and without sensible alteration in its character or quality. Any invasion of this right causing actual damage or calculated to found a claim which may ripen into an adverse right entitles the party injured to the intervention of the court.

These principles are applicable to public bodies as well as private persons. While private rights, however, may be overridden by the acquisition of a prescriptive right, public rights can not. Without exception the riparian communities which pollute the waters of the boundary rivers do so in violation of the principles of the common law.

Inadequacy of common law.

It must be observed, however, that the circumstances under which these principles were evolved have greatly changed, and the physical features of the boundary rivers differ very much from those of the streams of England, where the common law originated. When settlements had been made along our boundary waters to an extent that urban communities commenced to grow, and sewerage systems in consequence of this growth began to be installed, such was the immensity of these rivers that settlers living farther down stream probably neither noticed nor protested against the discharge into them of what was relatively an infinitesimal amount of pollution. When these communities, therefore, installed sewerage works they took advantage of the diluting powers of the rivers, and resorted to the simple and inexpensive expedient of discharging into them their sewage in its raw condition. The custom of doing so has now become universal. The selfishness of vested interests, familiarity with evil conditions, which has begotten an indifference to both the doing and the suffering of wrong, an ill-directed spirit of economy averse to the assumption of financial burdens to remedy what was only regarded as an existing or potential evil to other communities, and the disinclination to change ingrainted in humanity, have resulted in a situation along the frontier which is generally chaotic, everywhere perilous, and in some cases disgraceful. The common law having proved inadequate to the task of controlling affairs, it has been supplemented or superseded by legislative enactments, which in their practical working have about as signally failed.

Changed nature of problem of "injury."

The great difficulty is that in the United States and in Canada, as in all countries, in fact, modern development, social and economic, has introduced a number of new elements into the question of sewage purification which call for the reconsideration of views and methods which have fallen into disuse.

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Sanitary consideration first in order of procedure.

It must be admitted that the conservation of public health is of paramount importance under the treaty. This is evident from Article IV to which reference has been made. The significance of sanitary considerations is also evidenced by Article VIII of the treaty, which contains the following provisions:

> The following order of procedure shall be observed among the various uses enumerated hereafter for these waters (meaning boundary waters), and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of procedure:
>
> 1. Uses for domestic and sanitary purposes.
> 2. Uses for navigation, including the service of canals for the purposes of navigation.
> 3. Uses for power and for irrigation purposes.

"Injury" a complex question.

Although this order of procedure is in respect to certain uses enumerated in this particular article, it may be taken as indicative of the view of the high contracting parties regarding the importance of sanitation. Notwithstanding this, the discharge of sewage into streams can not be looked upon exclusively from the standpoint of its harmful effects upon health and property. The reference itself does not so look upon pollution. One of the questions in its second branch is, "By what means or arrangement can * * * a system or method of rendering these waters sanitary and suitable for domestic and other uses be best secured and maintained in order to insure the adequate protection and development of all interests involved on both sides of the boundary?" The growth and development of riparian communities would be seriously arrested if pollution were looked upon from this standpoint exclusively. While public health is the paramount consideration, it must be looked upon, however, as only one of a large number of elements in the many-sided and complex question of the public weal.

The pollution of rivers in England has been the subject of investigation by royal commissions which have been studying the question very thoroughly and almost continuously for about 50 years. Their investigations have covered nearly all the rivers of England and practically all the various phases of the problem of river contamination, and the voluminous reports submitted by them from time to time are very valuable and deserving of careful study. The conclusions and recommendations made in these reports, while recognizing sanitary considerations as first in order of precedence, are based upon the implied assumption that the solution of the problem lies in the proper balancing of the various conflicting elements existing in the individual cases.

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"Injury" as between lower and upper communities.

The parties who appeared before the commission discussed the question of "injury" almost entirely as viewed from two standpoints: First, from the standpoint of the relation between the riparian communities which pollute the waters of the streams and those communities which suffer in consequence of the pollution of their water supply; and, second, from the standpoint of the agriculturists, the floating population of summer resorts, casual visitors, picnickers, campers, yachtsmen, and crews and passengers of vessels frequenting boundary waters.

The difficulties arising from viewing the situation from the first standpoint will appear by considering the supposititious case of town "A" and town "B," the first town being situate above the other on the same bank of a boundary stream, the former discharging raw sewage from its sewerage system into the river, the latter being obliged to drink the water thus contaminated or to purify it at its own expense. To compel "A" to purify its sewage absolutely or completely would, under present conditions and in the present state of sanitary engineering practice, involve a financial burden too great for that town to bear, a burden which might retard its progress both industrially and in respect to population. On the other hand, to permit "A" to relieve itself of any reasonable financial burden by throwing its raw sewage on the waterworks intake of "B" and thus compelling that town either to drink contaminated water, or to assume an unreasonable financial burden in purifying it, would be an act of injustice which no fair-minded community, with a proper appreciation of the evil inflicted, would perpetrate or continue, and one to which no community should be asked to submit. If the harm which would be done "B" could be remedied, however, by the assumption of a financial burden which would be reasonable under all the circumstances of the case, there would not be an "injury" within the meaning of the reference or the treaty.

"Injury" from the standpoint of summer residents, etc.

From the second standpoint, that of the agriculturist, the floating population of summer resorts, etc., the question of "injury" under the reference is a much more difficult one. The shores and islands of the boundary rivers and lakes must particularly be considered. Their scenic attractions, their pure air and salubrious climate, their opportunities for bathing, fishing, and yachting, and their ease of access, affording facilities for rest, enjoyment, and health restoration to unlimited numbers, are invaluable assets, factors in progress and civilization which should not, unless under the pressure of absolute necessity, be destroyed. The harm done by existing pollution to bathing resorts can not be remedied except by preventing the discharge of sewage into the waters which flow to them. Contamination of the sources of the drinking supplies of these classes of people is a most serious matter. The millions whom it affects or may affect are

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more exposed to danger than are the urban inhabitants who draw their water supplies from public water systems. Such systems have been installed by sanitary engineers and generally afford a reasonably pure drinking water. These classes, however, have no such protection and it is difficult to devise adequate means of protection which they could utilize. The fact that they consist in a large measure of children, especially at the summer resorts, must also be taken into account. What would, therefore, be an "injury" to them might not be an "injury" to riparian communities with water-purification systems.

Definition of "injury" as used in the reference.

The commission regards the word "injury" when used in the reference or treaty as having a special signification—one somewhat akin to the term 'injuria' in jurisprudence. It does not mean mere harm or damage, but harm or damage which is in excess of the amount of harm or damage which the sufferer, in view of all the circumstances of the case, and of all the coexistent rights (if it be permissible to use the term in this connection), and of the paramount importance of human health and life, should reasonably be called upon to bear.

"Injury" in Detroit and Niagara Rivers.

In the case of the Detroit and Niagara Rivers pollution exists on one side of the boundary line which unquestionably is an "injury" within the meaning of the treaty to health and property on the other.

"Injury" in Rainy and St. John Rivers.

In the case of the Rainy River and the St. John River, pollution also exists on one side of the boundary line which is an "injury" within the meaning of the treaty to health and property on the other.

In the case of these four rivers the pollution is transboundary both in its effect and extension.

In the case of the other boundary rivers the commission is unable to say that at the present time pollution does exist on either side of the boundary line to the injury of property upon the other, although it is of the opinion that at times it does. As populations along their banks grow, pollution having both transboundary extension and transboundary effect will doubtless increase.

In the division of this report which treats of pollution having transboundary effects a broader view of the question of pollution is taken than the literal words of the reference and treaty might be thought to justify. In the broad view there expressed pollution exists throughout the whole range of boundary waters, which is an "injury" to health and property in both countries, and comes within the spirit of the prohibition of Article IV of the treaty. It is now necessary to consider the limits of permissible pollution, or the extent to which pollution which might cause this "injury" should be restricted.

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VI.—LIMITS OF PERMISSIBLE POLLUTION AND STANDARDS OF SEWAGE PURIFICATION.

Two distinct lines of policy with regard to the disposition of sewage in boundary waters were suggested to the commission. (1) To look upon them as open sewers for the reception of riparian pollution of all kinds, and (2) to restore the purity of the boundary waters as far and as fast as a comprehensive and adequate appreciation of all interests involved will permit.

The first policy would not only be contrary to the treaty and the principles of international law, but the continued discharge of untreated sewage into boundary waters by either country would, in the case of the Niagara and Detroit Rivers especially, be increasingly injurious to its own riparian communities farther downstream.

The advisory engineers in their résumé, which has already been set forth in full in this report, say:

Opinion of advisory engineers. "A" as to the discharge of raw sewage in boundary waters.

> While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters. (Sec. 6.)

"B" as to feasibility of purifying water after pollution.

> Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are safe for use after purification, provided that the load upon the purifiying mechanism is not too great and that a sufficient factor of safety is maintained, and further provided that the plant is properly operated. (Sec. 2.)

"C" as to utilizing streams for dilution.

> In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby. (Sec. 5.)

This "burden or responsibility" is a very important element to be considered in arriving at a standard of purification or the limits of permissible pollution. The advisory engineers were interrogated very fully on this subject at the New York conference and were pressed to define this limit in as exact terms as possible. Their answer is contained in the fourth section of their résumé:

"D" as to the load of purification plant.

> While present information does not permit a definite limit of safe loading of a water-purification plant to be established, it is our judgment that this

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limit is exceeded if the annual average number of *B. coli* in the water delivered to the plant is higher than about 500 per 100 cubic centimeters, or if in 0.1 cubic centimeter samples of the water *B. coli* is found 50 per cent of the time. With such a limit the number of *B. coli* would be less than the figure given during a part of the year and would be exceeded during some periods.

Commission's recommendations.

It is scarcely necessary to remark that the engineers are speaking of bacterial pollution only. In view of the present stage of progress in sanitary science, this limit or standard must be regarded as tentative. Their evidence shows that they regarded the question as profoundly affected by conditions and in no sense capable of absolute generalization. The commission agrees with the statement of principles set forth in these four sections. It therefore recommends that all sewage should, before being discharged into boundary waters, receive some purification treatment, and the degree of such treatment is to be determined in a large measure by the limits of safe loading of a water-purification plant.

To determine the extent of remedial treatment required in each particular case would involve consideration of the varied lines that have been followed by the commission throughout the present inquiry; the existence of pollution and of harm, actual or potential, to domestic or other uses, to public health, or property; the results of the engineering studies of feasible remedies; and the economic facts relating to the conservation of stream resources. It would require the balancing of the value of remedial measures in the terms of public good against the cost of the requisite improvements.

On the one hand, it is evident that the paramount importance of public health and the binding obligations of the treaty must be borne in mind. These make impossible the recommendation of such lenient remedial measures as would work economic injustice or would indorse officially the continued spoliation of a natural resource to the injury of the citizens upon both sides of these waters.

On the other hand, sewage-treatment requirements must not be made so excessive and unreasonable as to involve the cities and towns along these waters in an expenditure entirely unjustifiable. They should be reasonable and feasible from the standpoint of engineering construction, of adaptability to local conditions, of the availability of necessary lands, of outfalls and incident structures, and of costs.

In view of the fact that pollution in the Detroit and Niagara Rivers, and its transboundary effects therein, are much greater than in the other boundary waters, these two rivers will be treated as one class and the remaining boundary waters as another class.

The problem of necessary bacterial purification of the sewage discharged into the two former is one of extreme perplexity, owing to the difficulty or impossibility of obtaining definite and ample data

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and the relative importance to be attached to many of the factors which enter into it.

After a great deal of consideration the commission has, in view of all the circumstances of the case, come to the conclusion that for the present, and as an immediate step in the way of restoration of the purity of these streams, the communities responsible for the discharge of raw sewage into them should purify it to such an extent that the resulting average cross-sectional pollution in each river will not exceed the limit of safe loading for a water-purification plant.

In other words, the standard of purification required of these communities should be such that the streams after receiving their treated sewage would have a mean annual cross-sectional average of *B. coli* not exceeding 500 per 100 c. c.

Compliance with the requirements of this standard would not impose upon the riparian communities along these rivers discharging their sewage therein a burden which would be unreasonable or greater than that ordinarily imposed upon urban communities which purify their sewage.

Both water and sewage standards tenative.

It necessarily follows that this standard of sewage purification, being based upon a tentative standard of safe loading of water-purification plants, must itself be tentative. The growing appreciation of sanitation, the consequent demand for a higher degree of purity in water supplies, and the constant improvement that is taking place in the processes of sewage treatment tend to make a proper standard of sewage purification one of ever-increasing stringency. The discovery of a new and much more economical, or possibly a profitable, method of disposal of sewage, for example, would naturally lead to the adoption of a stricter standard of permissible pollution in heavily polluted streams. Furthermore, any limit of permissible impurity that might be established even temporarily for a given stream must be influenced largely by strictly local considerations.

The data necessary for the formulation of a fixed standard either of sewage purification or of water purification are not sufficiently well established at the present time. By more precise methods of experimental study there will doubtless be obtained in the future a more ample and accurate command of facts, which will admit of the determination of a more definite standard.

Better working rule required than bacterial standard.

In view of the difficulties and uncertainties of bacteriological technique, it is distinctly advantageous to have, if possible, a working rule which is more accurate and readily determinable than the bacterial standard suggested. Prof. Phelps, the consulting engineer, taking the results of the extensive investigations reported upon in the Progress Report as an index of the conditions actually

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existing, worked out, as will appear from his calculations on page 9 of his report to the commission, such a rule or standard.

He found that if the sewage of the cities be diluted in a stream flow of 4 cubic feet per second, per capita of the population, the resulting water will contain approximately 500 *B. coli* per 100 c. c. If the dilution is proportionately less than this, a corresponding degree of purification of the sewage will be necessary to maintain this final stream condition. Further investigations will no doubt make possible a more accurate statement of these relations, but, as the entire matter of standards is always subject to revision in the light of accumulated knowledge, it is considered that for all purposes of a present inquiry the practical equivalence of the dilution and the bacteriological standards may be accepted.

The case of boundary rivers standard of sewage purification in other rivers.

These standards are not applicable to rivers other than the Niagara and Detroit, but it is in no sense to be inferred, however, that remedial or protective measures are not required in their case where the effect of pollution based upon the entire cross section of the streams exceeds in every instance 4 feet per second per capita of the population.

As has been stated, the view of the advisory engineers is adopted that no untreated sewage should be discharged into boundary waters, but the commission considers it inadvisable at the present time to prescribe what the amount of treatment should be in the case of these remaining rivers. The sewage from each community along their banks must be considered by itself in respect of the degree of purification that is necessary, basing the standard on the reasonable use of the waters, the practical possibilities of remedial and protective measures, the economic value of stream purification, and also the economic value of stream pollution, proper regard being had to the public health.

After giving much attention to the question of standards of purification in these six boundary rivers the commission has come to the conclusion that the fixing of standards for them, and the subsequent modifications of those standards from time to time, should be left as hereinafter recommended to some authority clothed with the necessary power to deal with the question. This authority should also have power to vary, from time to time as conditions demand, the standards of sewage purification in the Detroit and Niagara Rivers.

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VII.—REMEDIAL TREATMENT REQUIRED.

The second branch of the reference is concerned with remedying and preventing pollution in boundary waters.

Second branch of reference.

In what way or manner, whether by the construction and operation of suitable drainage canals or plants at convenient points or otherwise, is it possible and advisable to remedy or prevent the pollution of these waters, and by what means or arrangement can the proper construction or operation of remedial or preventive works, or a system or method of rendering these waters sanitary and suitable for domestic and other uses, be best secured and maintained in order to insure the adequate protection and development of all interests involved on both sides of the boundary, and to fulfill the obligations undertaken in Article IV of the waterways treaty of January 11, 1909, between the United States and Great Britain, in which it is agreed that the waters therein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other?

Attitude of municipalities.

The question of securing treatment of the sewage discharged into boundary waters is one in respect of which, fortunately, the communities responsible for the pollution are inclined to take a reasonable view. At several meetings held by the commission the representatives of the various communities interested generally recognized the intolerable condition of boundary waters from a sanitary standpoint, and expressed their assent to any reasonable remedial measures the commission might suggest. Some objections were made to any disturbance of the existing order of things, but the commission was pleased with the sympathetic reception generally met with in dealing with this problem.

In this connection the following extract is given from the report made by Mr. Clarence W. Hubbell, consulting sanitary engineer of the city of Detroit, in November, 1916. It is at one and the same time the expression of the opinion of a well-known sanitary engineer and an evidence of the commendable attitude taken by him and the city of Detroit with respect to sewage purification.

In regard to the second part of the problem, as to what expense would be justified for sewage treatment, it is difficult to formulate an answer in terms of money alone. However, it is believed that, aside from the international features of the problem, the combined benefits which would accrue from a more cleanly water front, purer water at the bathing beaches and summer playgrounds, reduction in typhoid and other water-borne diseases, due to the use of sewage-laden water along the river front; betterment of raw-water supplies for the municipalities below the city, and the protection of Detroit's

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water from gross sewage pollution at times when the Detroit River flows backward, amply justify the expenditure required for sewage-treatment works as above outlined. In round figures, the cost would be about $6,000,000, and in my judgment the expenditure of this sum would be justifiable.

The duty devolving upon the commission in answering the first question contained in this branch of the reference is not to lay down any particular scheme of remedial works which the communities interested should adopt, but to ascertain whether or not there is any means by which the pollution of boundary waters can be prevented or remedied which is at once practicable and within their financial ability. Subject to the requirement that the remedial works should be ample to accomplish the desired results, the adoption of the particular type of works to be installed should be left to the communities themselves, which may be able to select more efficient and less expensive methods than those which the commission has found sufficient to work out the desirable standards of sewage purification.

Various types of sewage nuisance and treatment.

The art of sewage treatment has developed along divers lines, and there are available at the present time various types of treatment adaptable to the needs of varying conditions. The most important type of pollution is the bacterial contamination of drinking-water supplies. Sewage-polluted drinking water constitutes an actual or potential menace to health, so much so that the presence of the bacterial organisms of water-borne diseases in the sewage of an urban community should always be assumed. While bacterial pollution is most serious in the case of waters used as sources of drinking-water supply, it is also serious in the case of waters used for bathing, boating, and other pleasurable exercises, and also, although to a less degree, in the case of shore waters on account of possible indirect infection through cattle and insects.

Certain types of sewage treatment processes, such as sand filters, having as their chief function oxidation of sewage, are incidentally more or less efficient as a means of disinfection; but sewage disinfection as a primary requirement is most economically and efficiently carried out by chemical means. Among the various chemical agents that have been proposed from time to time and extensively used for this purpose, calcium hyperchlorite or bleaching powder has proved most satisfactory.

Physical pollution.

A second type of pollution or nuisance arising from the discharge of sewage into boundary waters is physical and relates primarily to the condition of streams, as floating matter, turbidity, deposits upon the bottom or banks, and unsightly appearances. Sewage screening by means of so-called coarse screens will remove a considerable portion of the larger and more undesirable floating matter and improve the

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appearance of streams. Efficient sedimentation will remove a substantial part of suspended matter generally and nearly the whole of the suspended matter which is capable of settling and producing bottom deposits of an offensive character. Fine screening is intermediate in effectiveness between coarse screening and sedimentation. The requirements of each particular situation and the relative cost of the installation and operation of these three systems must determine in each case the type of treatment to be adopted. There is a third type of nuisance, chemical in its nature, which arises from changes in the chemical characteristics of streams—reduction in the normal degree of aeration, development of offensive odors, and discoloration and banishment or destruction of fish life. It is due to the oxidizable character of the polluted waters. Partial improvement results from screening or sedimentation by the removal of a portion of the oxidizable matter. Biochemical oxidation of sewage, which is the most effective treatment, is brought about by passing it through natural or specially prepared beds of sand or over the surface of stones or other coarse material or by passing it through tanks, with artificial aeration in contact with sludge properly cultivated (activated sludge), for the development of oxidizing organisms.

With the extension of stream pollution by increasing population these three kinds of nuisance appear in the chronological order in which reference has been made to them. A minor physically undetectable pollution may seriously injure a stream bacterially, and a stream may be physically affected by floating débris and deposits, and yet, from a chemical standpoint, be normal or practically so. The final result of continuously increasing pollution is the chemical breakdown of a stream, resulting in the most objectionable conditions, examples of which are becoming increasingly common in the more densely settled sections of both countries. In purely local situations in the Niagara, Detroit, and St. Clair Rivers, for instance, notably in the vicinity of sewer outlets and the mouths of tributary streams, and in the inner harbor at Buffalo, the waters are polluted to the extent of definite chemical nuisance. At these points the difficulty is due to incomplete dispersion of the sewage permitting the overloading of the immediate waters. The rivers as a whole, however, are far removed from this condition.

It is advisable to consider the Niagara and Detroit Rivers as a class by themselves so far as remedial and preventive systems are concerned. As has been stated, the most serious condition existing is the bacterial pollution of these streams. To remedy this evil, sewage treatment should be applied in connection with dilution so far as is necessary to bring their waters to the standard mentioned—a mean annual cross-sectional average of *B. coli* not exceeding 500 per 100 c. c. This necessary sewage purification can be effected by fine screen-

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ing or sedimentation, and when necessary by chemical disinfection, at a cost which will impose no unreasonable burden upon the urban community responsible for the present pollution.

Cost of remedial works at Buffalo and Detroit.

The consulting engineer, Prof. Phelps, investigated the question of installing adequate remedial works at Detroit and Buffalo. The results of his investigation are given in his report to the commission, to which those desirous of looking into this question at length are referred.[1] A summary of his conclusions, however, is given in the following table:

	First cost.				Annual charges.			
	Interceptors.	Other structures.	Land.	Total.	Fixed.	Operating.	Total.	Per capita.
Detroit	$2,560,000	$2,690,000	$680,000	$5,930,000	$295,000	$216,000	$511,000	$0.54
Buffalo	1,560,000	1,770,000	270,000	3,600,000	203,000	187,000	390,000	.65

The estimated first cost of necessary remedial works for Detroit is about $6,000,000, and for Buffalo something less than $4,000,000. In each case about one-half of the total costs is for treatment works proper, the remainder being the amount chargeable to the collection of sewage. The annual charges include interest, maintenance, and operating expenses, and amount on a per capita basis to 54 and 65 cents, respectively.

The United States Census Bureau furnishes data[2] respecting the combined yearly charges per capita for water and sewerage works in American cities. Tabulated, these data are as follows:

Cities over 500,000 population	$3.48
Cities from 300,000 to 500,000	4.01
Cities from 100,000 to 300,000	3.92
Cities from 50,000 to 100,000	3.71
Cities from 20,000 to 30,000	3.65
Average of all cities over 30,000 population	3.94

These estimated yearly costs per capita for required sewage treatment determined by Prof. Phelps do not appear to the commission to be unreasonable, either in view of the combined water and sewerage costs in the United States cities or in view of the financial standing of the communities interested.

Other rivers.

The sewage pollution of the Rainy, St. Marys, St. Clair, St. Lawrence, St. John, and St. Croix Rivers differs from that of the Detroit and Niagara Rivers in degree, but not in kind. The less concentrated populations on these six rivers have not yet brought about the regrettable condi

[1] Report of the Consulting Sanitary Engineer Upon Remedial Measures, Mar. 6, 1916.
[2] U. S. Census Bureau. Financial Statistics of Cities, 1912. Washington, 1913.

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tions existent in the other two. A fortunate opportunity, therefore, is afforded them to avoid the dilemma of the more dense populations along the Detroit and Niagara Rivers and to profit by recent advances in sanitary science and provide at an earlier stage in their development facilities and arrangements for sewage purification, the absence of which makes stream protection in the Niagara and Detroit Rivers a matter of such serious expense and difficulty. Despite the fact that the effects of pollution in these six streams are largely local and confined in the main to shore conditions, the commission has no doubt as to the advisability of their adopting remedial measures in the immediate future. The extent of treatment required is controlled by local rather than by general conditions. By this statement it is meant that while conditions exist in many instances which are in substantial contravention of treaty obligations, their immediate local effect is much more serious than their effect upon the stream as a whole. Remedies sufficient to meet the local conditions would be ample to meet the international situation.

In the case of these streams any remedial works installed in compliance with existing legislation, and the regulations of the States and Provinces directly affected, should have in view the safeguarding of international interests, present and future. These interests require as a minimum measure the planning of a sewer system with provisions for the collection of sewerage at one or more points suitable for treatment, the installation of tanks or other devices sufficient for the removal of the larger portion of the suspended solids capable of settling, and ample equipment for the chemical disinfection of all sewage at such times as may be found necessary, the time for taking these remedial measures to be left to the discretion of the authority hereinafter recommended.

The consulting engineer also investigated the question of the cost of adequate remedial works at the following towns in the Province of Ontario: Windsor, Sarnia, Amherstburg, Fort Erie, Niagara Falls, Bridgeburg, Chippewa, and Queenston; at the following towns in the State of Michigan: Port Huron, St. Clair, Marine City, Algonac, River Rouge, Ecorse, Ford City, Wyandotte, and Trenton; and at the following towns in the State of New York: Tonawanda, North Tonawanda, Lasalle, Niagara Falls, Lackawanna, Kenmore, Lewiston, and Youngstown.

In the case of these cities and towns the estimated annual charges in connection with these works, including interest, maintenance, and operating expenses, range from 44 cents to $2.49 per capita, averaging 77 cents per capita of their population. These estimates, as well as the estimates in the case of Detroit and Buffalo, are based on ordinary prices and not on the exceptional prices which, owing to the war, are ruling at the present time. These charges also appear to

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the commission to be reasonable, both in view of the financial standing of the towns and cities and in view of similar charges in the case of other towns and cities in the two countries.

Inquiries into methods of sewage disposal.

Although the commission felt itself more concerned with results than methods, it devoted considerable time and attention to the investigation of improved processes of sewage treatment and disposal. The science of sanitation, as has been remarked, is a progressive one, and its advance is marked by important developments from year to year.

Mr. T. Chalkley Hatton, sanitary engineer for the city of Milwaukee, gave evidence before the commission on this subject.[1] One of his statements illustrates the active spirit of research along this line which to-day characterizes the world of sanitary science. He says:

> Before deciding upon the methods of sewage disposal for Milwaukee we built rather an elaborate experimental station, in which we tried to put all those modern methods of sewage disposal now prevalent in this country and abroad, and I think we had 23 different processes going on there at one time—one of the largest experimental stations carried on in this country for sewage-disposal purposes.

A controlling factor in the disposal of sewage is the cost of dealing with the sludge. Great care must be taken in disposing of the settleable solids of sewage in order to prevent local nuisances, and under certain conditions very large expenditures must be made to prevent the substitution of nuisances on land for nuisances in the water of the diluting streams. What sanitary engineers generally are seeking for is some effective process by which the disposal of the sludge can be made a commercial success.

The activated sludge process, which has apparently been finally adopted by Milwaukee, is one of the most promising of modern methods and is meeting with the approval of a large number of sanitary engineers.

A sludge-treatment process operated in England was discussed before the commission by Mr. Edward A. Paterson, chemical engineer of London.[2] The object of this process is to dry prepared sewage sludge so that it can be used as a fertilizer and extract as by-products during destructive distillation, ammonia, oils, gas, fat, phenol, and other materials suitable for drugs and dyes. Mr. Paterson claims that the sludge can be and is being treated by this process in England at a fair profit. Other processes were looked into. Of all of them it may be said that they are still in their experimental stage, and while their results so far have under certain circumstances been very encouraging, they have not been fully tested by time and condi-

[1] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada, 1916, p. 99.
[2] Ibid., p. 35.

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tions. A full discussion by the commission of these various processes in their present stage of development would not serve any useful end, and its opinions would not be taken, and could not be expected to be taken, as conclusive as to their respective merits.

So far remedial methods have only been dealt with in connection with urban communities. Sewage from vessels, water ballast discharged from vessels, garbage, industrial and manufacturing wastes call for consideration with regard to remedial methods.

Vessel sewage.

The discharge of sewage from vessels has been shown to constitute a series menace to public health in both countries, not only through the possible contamination of water supplies near their intakes, but also by reason of its effect upon the water supplies of other vessels traversing the same areas. Experiments undertaken by the United States Public Health Service have shown that by the use of steam this sewage can be easily disinfected before discharge. A practical test of an automatic apparatus designed for this purpose carried out through two complete seasons upon the *D. C. Kerr*, a lake steamship, met with entire success both as to mechanical operation and bacteriological efficiency. The installation of this apparatus would be quite inexpensive and all steamships on boundary waters should be compelled to sterilize their sewage. Since the navigation of these waters is almost entirely by steamship, the evil now caused by this sewage would be practically remedied. In the case of other vessels some system of purification can doubtless be found which is cheap and practical.

Vessel ballast.

Pollution by water ballast constitutes a more difficult problem. There has not yet come to the notice of the commission any feasible means of purifying the rather large quantities of water which vessels while in the polluted areas of inner harbors frequently take on board for purposes of ballast, and which they afterwards discharge upon approaching their ports of destination, often while passing water intakes. It will probably be sufficient for the present at least to control this practice by suitable regulations, designed to limit or prevent the discharge of water ballast in the neighborhood of intakes. In the event of the failure of such control by regulations, more expensive and time-consuming methods of treatment will have to be developed and prescribed.

Garbage.

The floatable character of garbage generally renders it liable to be carried by winds to the shores of the rivers and lakes, where, within a limited radius, it becomes particularly offensive. In the case of one American city of considerable size a substantial part of its garbage was being disposed of by dumping it into the main outfall sewer near its mouth. Such a practice is highly censurable and out of keeping

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with the usual practice of American cities. The remedy for pollution from this source is to prohibit the discharge of all garbage into boundary waters.

Industrial wastes.

Pollution from industrial wastes has received a great deal of attention, and expensive works for its purification have been installed both in this continent and in Europe. In some of these works valuable by-products have been recovered, and the cost of treatment thus reduced. The immensity of the boundary waters, and their consequent capacity for dilution, will probably for some time to come prevent pollution from this source other than sawmill and pulp mill wastes becoming an international question. Having regard to the future, however, it is well to provide for its regulation. Specifically the dumping of large quantities of sawdust and other sawmill waste, and the discharge of wastes from pulp mills, have been brought to the attention of the commission. Sawmill waste has in many States and Provinces been prohibited by laws, more honored in their breach than in their observance. It is possible that there will come a time, and not in the very distant future, when all sawmill wastes will become valuable and be utilized in manufacturing; but in the meantime these wastes should be burned, or otherwise prevented from being discharged into boundary waters. At present the St. John Lumber Co.'s sawmill on the St. John River at Van Buren, Me., disposes of all its sawmill waste in connection with the pulp mill in its vicinity, and none of it is permitted to enter the St. John River. Other cases, including wastes from manufacturing and chemical industries, may demand further investigation of a somewhat detailed character before it will be possible to determine the extent of the resulting injury and the feasibility of remedial measures. The nature of the treatment of this waste and the degree of its purification necessary will have to be determined upon the facts and circumstances of individual cases as they arise. The dealing with this class of pollution should be left to the authority hereinafter recommended.

Drainage canals.

The reference specifically calls for consideration by the commission of drainage canals as a possible way or means of remedying or preventing the trans-boundary effect of pollution. The only suggestion that has been made before the commission of a drainage canal project is of that promoted by the Erie & Ontario Sanitary Canal Company. This company was organized primarily for power purposes, but among the objects in its application for incorporation is remedying the pollution of the Niagara River by the construction of a canal starting at or near the mouth of Smokes Creek in the city of Lackawanna and thence running through a well-settled country to Lake Ontario. It is proposed that the canal should be used free of charge

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by the cities of Lackawanna, Buffalo, Tonawanda, North Tonawanda, Niagara Falls (United States), and Lockport, and by all other municipalities and communities on the United States side of the Niagara River to carry off their sewage and storm flows, which are now discharged into Lake Erie and the Niagara River, provided each city or town make its own connection with the canal without expense to the company. The company applied to the Secretary of War for the United States by application dated April 23, 1912, for permission to divert for its purposes 6,000 second-feet of water from Lake Erie and the Niagara River. The necessary authority for the diversion of this water was denied by the Government of the United States, but the company desired to secure from the commission an approval of the canal as a feasible solution of the pollution problem in the Niagara River. Opportunities were afforded the company to appear before the commission on several occasions. The company's president, Mr. Millard F. Bowen, its counsel, Mr. George Clinton, and others on its behalf made at the different sittings able and lengthy arguments, and briefs were submitted to the commission containing statements of fact and arguments from Messrs. Randolph, Clinton, Bowen, and Shiras in support of the scheme. Quite a large amount of evidence was taken, as will appear on reference to the records of the commission.[1] The financial and sanitary features of the project did not, however, appear to have been sufficiently investigated. The plans and data submitted were consequently referred to the consulting engineer for further investigation and report. His report was decidedly adverse to the undertaking for two principal reasons: (1) It proposes to receive sewage in its raw condition into the canal, thus creating a large open sewer. A condition of serious menace would therefore obtain throughout its length; and if the sewage were allowed to pass into Lake Ontario, conditions there would be at least no less objectionable than they are at present. (2) The treatment required to prevent nuisance in such a canal would necessarily be more complete and correspondingly more expensive than treatment required for the protection of the Niagara River—a result due to the comparatively small volume of diluting water available in the canal and the consequent necessity for thorough treatment of the sewage by expensive oxidizing methods. These reasons would apply with much greater force in the future. Buffalo and the towns below are rapidly growing. Should their combined population reach a total of 1,000,000, the diluting power of the diverted water would be so inadequate that

[1] Preliminary report of committee having general supervision of the investigation relating to the pollution of boundary waters, with documents * * * relating to the petitions of the Erie & Ontario Sanitary Canal Co. for permission to divert 6,000 second-feet from Lake Erie, 1913.

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during the summer months the waters of the canal would be devoid of oxygen, dark in color, and foul smelling. One nuisance would be abated by the creation of a much greater nuisance, which could only be corrected by the most intense sewage purification. The commission, after full consideration of all the features of the project, is of the opinion that besides being objectionable on other grounds it is inadvisable as a sanitary measure.

On the general question of drainage canals as a method of sewage disposal the commission is unable to express any opinion, as each case must be decided upon its merits. Consideration of any scheme involves a study of the amount of water available for diversion, the water-carrying capacity of the canal, the amount of raw sewage to be discharged into it, the character and cost of treatment of the sewage to be carried, and the consequent interference with the many other interests which may be affected, all of which elements vary according to local circumstances and conditions.

General question of pollution should be considered and controlling authority constituted.

In the discussion of sewage standards and purification and other matters in this report it was recommended that they be dealt with by some authority which should be clothed with the necessary power. In view of what has been said under the heading of "Transboundary effect of pollution," the commission is of the opinion that to the extent that is consistent with a proper degree of autonomy by the urban communities interested, all boundary waters, so far as pollution is concerned, should be subject to the regulations prescribed by this authority. If, during the investigation, one thing impressed itself more than another upon the attention of the commission, it was the view that while pollution which has a transboundary effect must in consequence of the obligation resting on both countries under the treaty be distinguished from pollution which has not such an effect, the distinction is, from a practical standpoint, highly technical and artificial. The question of pollution, if a narrow construction be placed upon the treaty and reference, is but a part of the larger question of pollution in boundary waters generally, in the solution of which both countries are, as has been shown, vitally interested. The present international situation is not the result of any desire on the part of the inhabitants of either country to ignore international obligations either of comity or of law, but is the outcome of the failure on the part of the urban communities in each country, respectively, to recognize from a sanitary standpoint any right in other communities to river waters, especially communities on their own side of the boundary line. Every border community in the United States and Canada has in the matter of sanitation considered its own immediate interests exclusively. The result is that while those communities have been tolerably successful

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in the management of sanitary affairs within their own territorial limits and have installed water and sewerage systems fairly ample for their own present needs, they have recognized no responsibility whatever resting upon themselves with regard to their sewage effluents, and by discharging them untreated into river waters they have compelled their neighbors to submit to intolerable conditions. The present practice of discharging sewage in this manner must be restricted until an equilibrium, so to speak, of the rights of all communities in the waters of the boundary rivers is established, in which each may discharge its sewage into these waters, but only to such an extent and of such a degree of purification as shall not interfere with the reasonable enjoyment by other communities of their rights.

The situation on the boundary waters is not unique; many like it exist elsewhere, although not on so large a scale. A close parallel exists in the case of the boundary waters between England and Scotland. By act of the British Parliament passed in 1898 the local government board for England and the secretary for Scotland may, on certain steps being taken, "together constitute a joint committee representing all or any of the countries through or by which such river or any specified portion or tributary thereof passes; and such committee may have all the powers of a sanitary authority with respect to pollution in such waters."

In this connection reference may be made to the views of the British royal commissions already mentioned whose extensive and exhaustive investigations into river pollution, most scientifically conducted for a lengthened period, entitle their opinion to great weight. Their reports, especially the reports of the last commission, repeatedly emphasize the great necessity for sanitary purposes of having a river, as a whole, under one management.

Under existing sanitary laws and their administration the pollution evil has been steadily growing along the boundary. The indifference to injury done others, the financial interests of the different communities, and the practical difficulties in arriving at concerted action are so hard to overcome that the only assurance of betterment lies in the constitution of some authority which shall have jurisdiction over boundary waters and be clothed with ample power to prevent their being unduly polluted. Consistently with the exercise of its powers by such an authority, the installation of remedial works and the expenditures in connection therewith would all be in the hands of the local authorities. The only interference with the latter on the part of the suggested authority would be to prescribe the necessary capacity of the sewage-purification works and the degree of efficiency with which they should be operated. From the international standpoint this capacity and degree of efficiency need

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not exceed those which should prevail for the protection among themselves of the communities on either side of the boundary line.

As has been remarked, the question of the pollution of those waters generally is a matter of great international moment. In view of this fact and of the variety and possible conflict of national State, provincial, and municipal authorities, it is too obvious to require discussion that the recommended authority should be jointly created by the high contracting parties. As the International Joint Commission is under the treaty clothed with jurisdiction over the use, obstruction, and diversion of boundary waters, together with jurisdiction over other international matters, it is recommended that the necessary jurisdiction and authority in respect of the pollution of boundary waters and waters crossing the boundary be conferred upon it; and for the purpose of giving effect to the jurisdiction and authority so conferred that the commission be authorized to make such rules, regulations, directions, and orders as in its judgment may be deemed necessary; and that power be also given to the commission to appoint such engineers and employees as it may consider advisable

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VIII.—CONCLUSIONS AND RECOMMENDATIONS.

The following is a summary of the conclusions the commission has arrived at, and of the recommendations it submits to the two Governments:

1. The Great Lakes beyond their shore waters and their polluted areas at the mouths of the rivers which flow into them are, except so far as they are affected by vessel pollution, in a state of almost absolute purity. With the exception of these pure areas, the entire stretch of boundary waters, including Rainy River, St. Marys River, St. Clair River, Detroit River, Niagara River, St. Lawrence River from Lake Ontario to Cornwall, and the St. John River from Grand Falls to Edmundston, New Brunswick, is polluted to an extent which renders the water in its unpurified state unfit for drinking purposes. This pollution has its origin chiefly in the sewage and storm flows from the riparian cities and towns and the sewage from vessels. It is very intense along the shores of the Detroit and Niagara Rivers and in the contaminated areas in the Lakes. Throughout the whole length of the boundary waters where sewage is discharged from the sewerage works of cities and towns the pollution is most concentrated in the shore waters on the side of the boundary on which it originates. These shore waters, besides being in places unsightly, malodorous, and absolutely unfit for domestic purposes, are a source of serious danger to summer residents, bathers, and others who frequent the localities. So foul are they in many places that municipal ordinances have been passed prohibiting bathing in them.

2. In the Detroit and Niagara Rivers conditions exist which imperil the health and welfare of the citizens of both countries in direct contravention of the treaty. This is true, though in a less marked degree, of the Rainy and St. John Rivers.

3. In the St. Marys, St. Clair, and St. Lawrence Rivers pollution exists which is in substantial contravention of the spirit of the treaty, and unless these conditions are improved, and the rivers placed under the control of competent authority, the resulting injury will be much more pronounced as population increases.

4. Vessel pollution in certain parts of boundary waters exists to an extent which causes substantial injury to health and property. It is derived from two sources, sewage waste from vessels and "water ballast" which is taken in by lake vessels at their ports of departure and emptied into these waters at or near their ports of destination. Vessel pollution is distinctly traceable in boundary waters in lanes and channels which vessels traverse in navigating

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them, their waters being thereby rendered unfit for drinking purposes.

5. In some cases sawmill and other mill wastes, garbage, offal, carcases, and other refuse matters are discharged into boundary waters. This practice results generally in a contravention of the treaty.

6. It is feasible and practicable, without imposing an unreasonable burden upon the offending communities, to prevent or remedy pollution, both in the case of boundary waters and waters crossing the boundary.

(*a*) In the case of city sewage, this can best be accomplished by the installation of suitable collecting and treatment works, the latter having special reference to the removal of bacteria and matters in suspension.

(*b*) In the case of vessel sewage, a feasible and inexpensive remedy lies in the employment of recognized methods of disinfection before it is discharged. In the case of water ballast suitable rules and regulations should be prescribed with a view of protecting the water intakes.

(*c*) The discharge of garbage and sawmill waste into boundary waters should be prohibited, and industrial and other wastes, which are causing appreciable injury, should be discharged subject to such restrictions as may be prescribed.

7. In order to remedy and prevent the pollution of boundary waters and to render them sanitary and suitable for domestic purposes and other uses, and to secure adequate protection and development of all interests involved on both sides of the boundary, and to fulfill the obligations undertaken in Article IV of the treaty, it is advisable to confer upon the International Joint Commission ample jurisdiction to regulate and prohibit this pollution of boundary waters and waters crossing the boundary.

Hereto annexed is a schedule showing the reports made to and by the commission, and of the minutes of its sittings, which have already been printed, or which the commission contemplates having printed.

Dated at Atlantic City, N. J., this 12th day of August, A. D. 1918.

CHARLES A. MAGRATH.
OBADIAH GARDNER.
HENRY A. POWELL.
JAMES A. TAWNEY.
P. B. MIGNAULT.
R. B. GLENN.

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SCHEDULE.

LIST OF PUBLICATIONS OF THE INTERNATIONAL JOINT COMMISSION RELATIVE TO THE POLLUTION OF BOUNDARY WATERS.

1. Preliminary report of the committee having general supervision of the investigation relating to the pollution of boundary waters, with documents on file in the United States War Department relating to the petitions of the Erie & Ontario Sanitary Canal Co. for permission to divert 6,000 second-feet from Lake Erie for the purpose of remedying the existing pollution of Niagara River. Washington, 1913.

2. Progress report of the International Joint Commission on the reference by the United States and Canada in re the pollution of boundary waters, whether or not such pollution extends across the boundary in contravention of the treaty of January 11, 1909, and, if so, in what manner or by what means is it possible to prevent the same, including report of the sanitary experts. Washington, 1914.

3. Pollution of boundary waters. Conference with sanitary engineers at New York City, May 26 and 27, 1914. Washington, 1914.

4. Résumé of testimony of consulting sanitary engineers in the matter of the pollution of boundary waters. Conference at New York City, May 26–27, 1914. Washington, 1914.

5. Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada, held at Niagara Falls, Ontario, Buffalo, N. Y., Detroit, Mich., Windsor, Ontario, Port Huron, Mich., and Sarnia, Ontario, September 25 to October 2, inclusive; Detroit, Mich., November 10 and 11; and Washington, D. C., December 14 and 16, 1914. Washington, 1914.

6. Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada, being public hearings held at Buffalo, N. Y., and Detroit, Mich., June 21–27, 1916, and Ogdensburg, N. Y., August 25, 1916. Washington, 1917.

7. Report of the consulting sanitary engineer upon remedial measures. March 8, 1916. Washington, 1918.

8. Final report of the International Joint Commission in the matter of the reference by the United States and the Dominion of Canada relative to the pollution of boundary waters. Washington, 1918.

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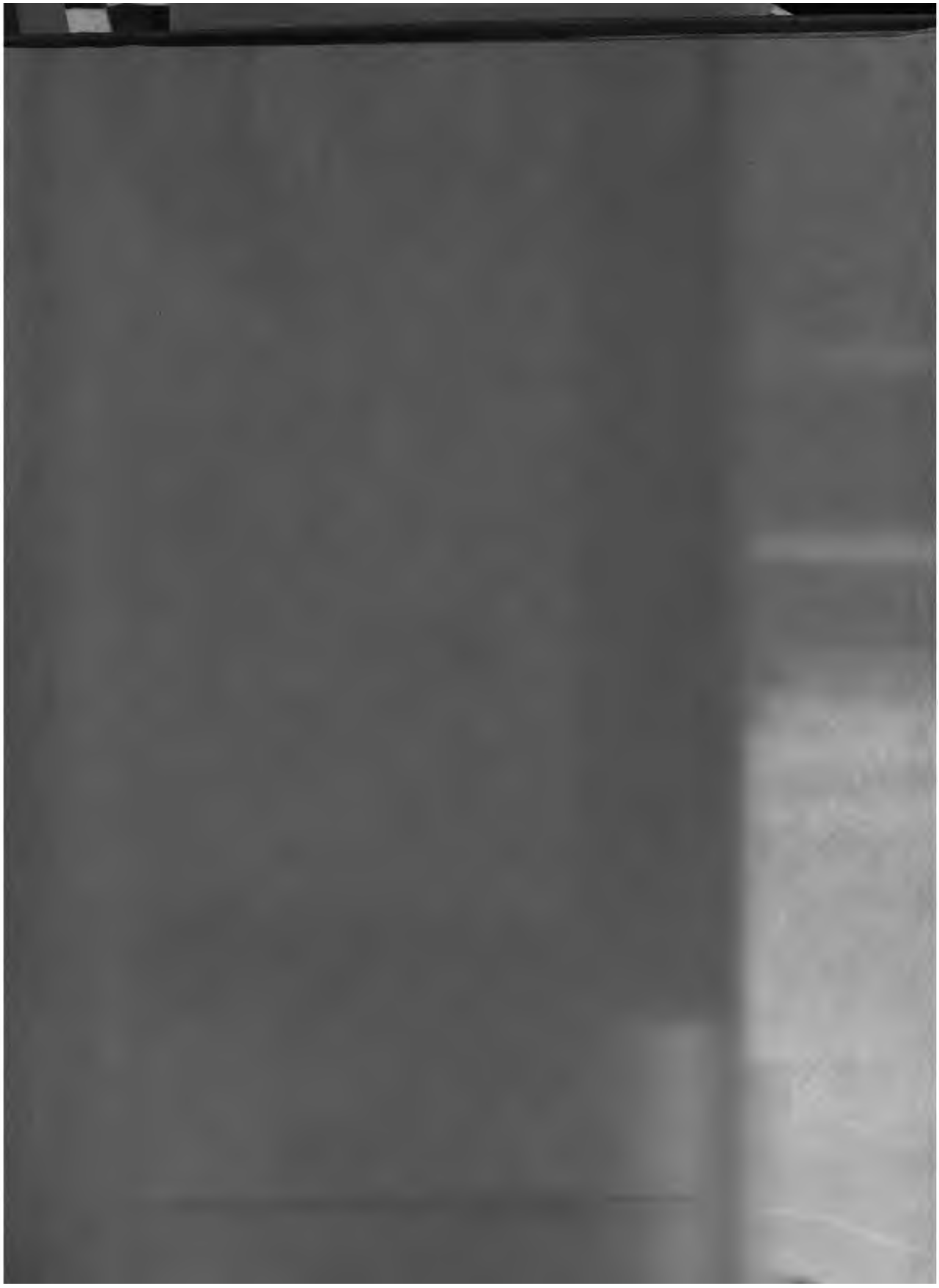

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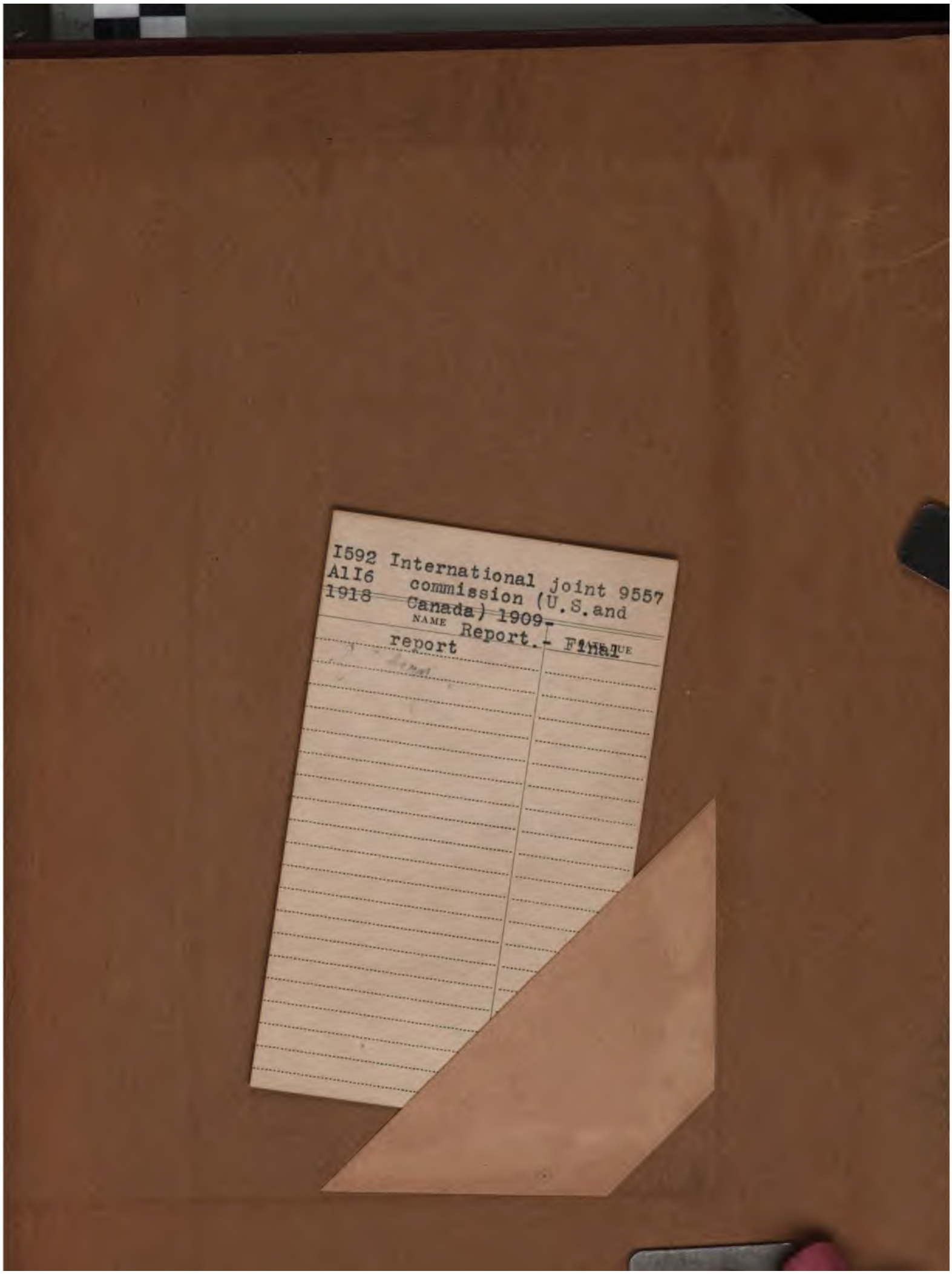

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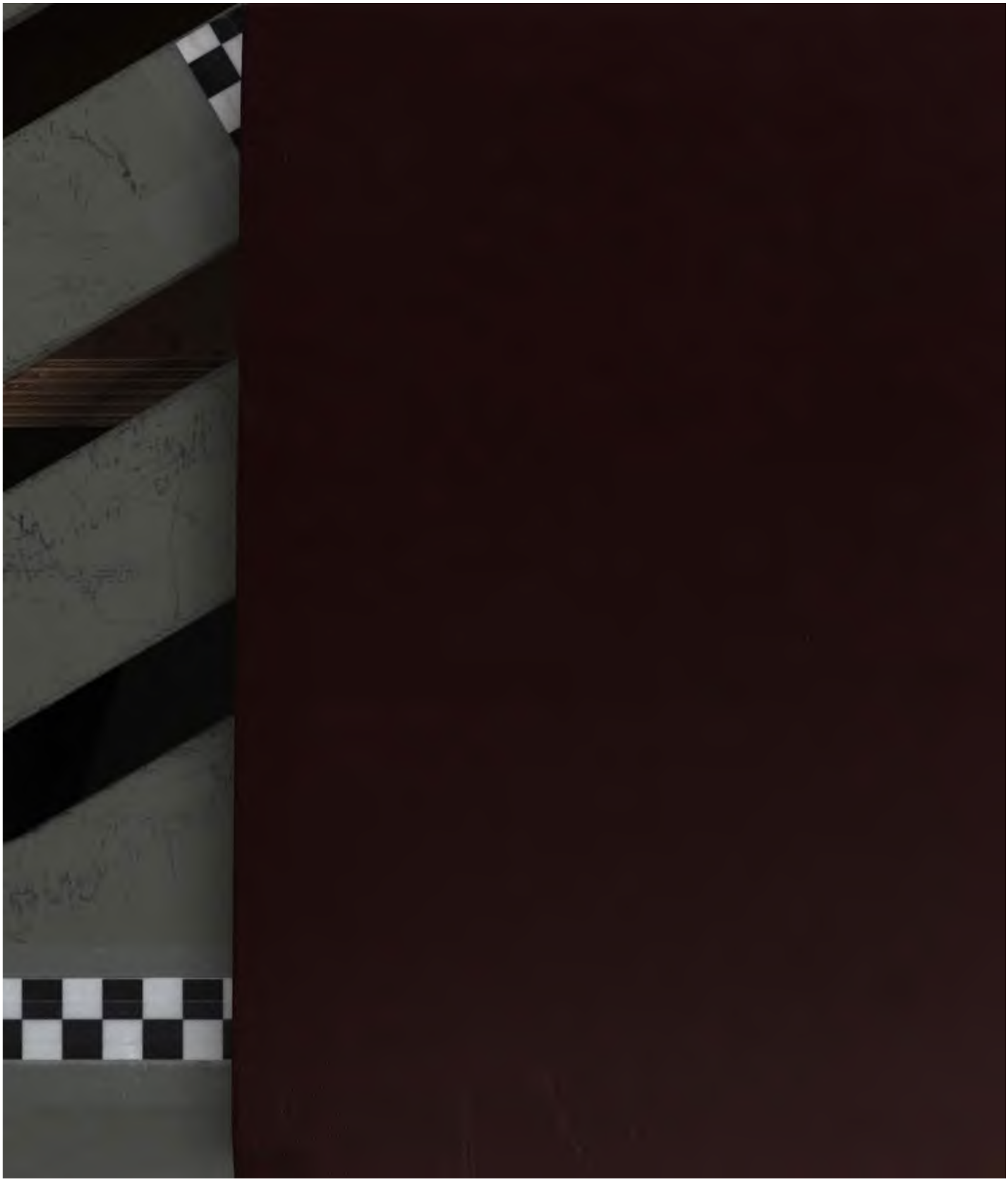

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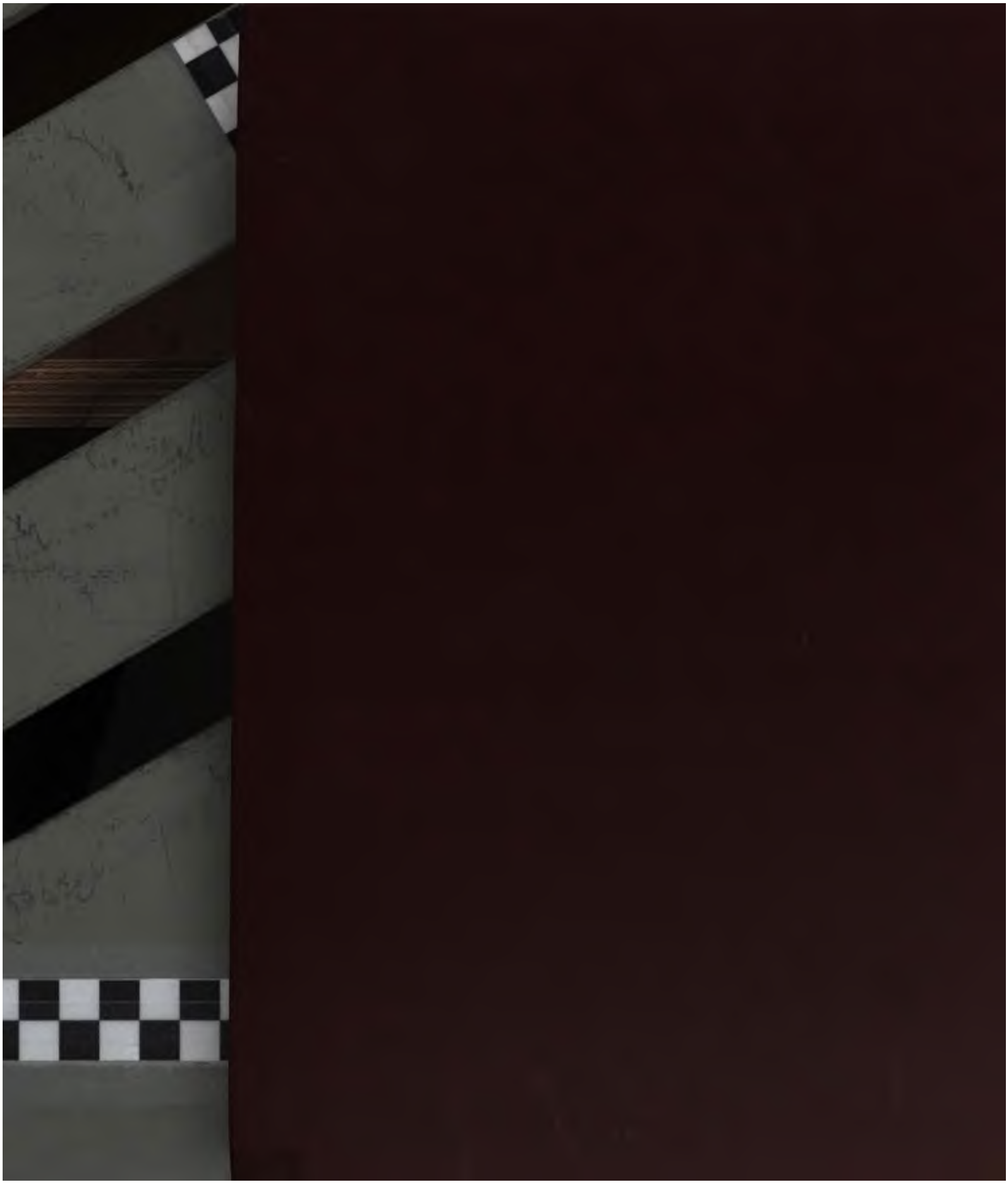

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